

140368

APOLLO/BOYD'S SOFT PROGRAM

Management Systems Study

## Systems Analysis

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Contract NAS 9-6100

April 30, 1972

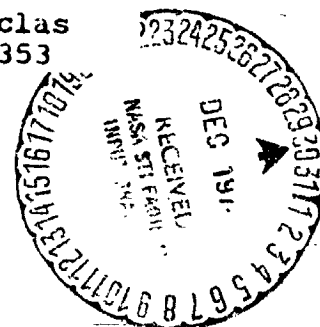
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1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

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FOREWARD

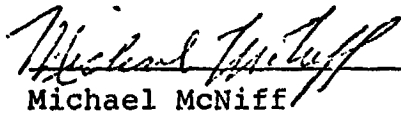
Apollo/Skylab Suit Program Management Systems Study

Study Duration December 17, 1973 through April 30, 1974

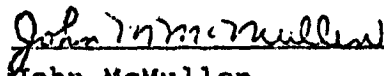
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Contract NAS 9-6100



- SECTION 1 -  
INTRODUCTION

## 1.0 INTRODUCTION:

A management systems study for future spacesuit programs was conducted by ILC Dover, a division of ILC Industries, Inc., during the calendar period of December 17, 1973, through April 30, 1974, in response to SA 606S (Schedule IV) contract NAS 9-6100, issued by NASA Johnson Spacecraft Center (JSC). This study included the investigation of past suit program requirements and management systems in addition to new and modified systems in order to identify the most cost effective methods for use during future spacesuit programs. This report highlights the effort and its findings.

Past space suit programs have required the contractor to comply with the overall NASA program requirements of NPC 200-2, NPC 250-1, and NPC 500-1. These requirements encompassed development and production of all hardware ranging from crew protective gear to total launch vehicles, yet each class of hardware was unique in design, development, testing, manufacturing and inspection criteria. The complexity of these requirements necessitated significant contractor staffs for program compliance. Inevitably, extraneous and redundant areas of documentation, data and program management control were generated. The identification of a set of requirements specifically tailored to the space suit is considered essential to achieve significant cost reductions.

It is recognized, however, that the establishment of a complete set of specialized program requirements and associated systems for future spacesuit programs would be expensive. As a result, this study has investigated alternate approaches in order to determine the least costly method of control, both from an implementation and operational standpoint.

Past spacesuit programs have been extremely dynamic with the emphasis concentrated on mission assurance. Systems were increasingly more complex and expensive to develop and maintain with the advent of each new program. Future programs will require fewer controls and redundant checks and balances. To fully realize the inherent reduction of

overall program costs, without compromising end item integrity, the management systems for these future programs must be structured accordingly. This report investigated several major management systems used during the past Apollo, Skylab, and ASTP spacesuit programs. Topics to be discussed within this report include:

- a. Significant Conclusions - Section II: This section summarizes the important conclusions and recommendations resulting from the study. A detailed explanation of these conclusions is contained in the applicable portion of Sections III through VI.
- b. Program Management Engineering and Quality - Sections III through V: This section discusses the various difficulties experienced with the systems and procedures that controlled the inter-relation of these groups. Recommendations or guidelines for future spacesuit programs are also included.
- c. Organization and Cost Summary - Section VI: This section discusses the recommendations for a future space suit program organization and forecasts the cost savings.

## 1.2 OBJECTIVE:

Requirements and management systems used during the Apollo, Skylab, and ASTP spacesuit programs were analyzed. Requirements with the greatest cost savings potential as well as new systems and modifications of existing systems were evaluated. Trade-off's of these requirements and management systems were performed to determine the most cost effective methods for the management of future space suit programs.

### 1.3 STUDY GROUND RULES:

The following items include the basic ground rules used to establish the guidelines or recommendations discussed in Sections II and III through VI:

- a. The ILC Management Systems in effect during the A7LB Program were used as study baseline.
- b. Cost Savings are identified in terms of reduced man months (by skills) to perform similar efforts on future programs.
- c. Recommendations are presented as guidelines for future programs.
- d. Proposed guidelines are based on state-of-the-art advancements in suit designs expected to be used on future programs.
- e. The delivery rate is assumed to be one (1) space suit every 20 working days.
- f. On future programs, only one (1) cycle Qual is assumed to be performed using the worst case projected mission(s) through the life of the CEI.
- g. The requirements of NHB 5300.4 will be applicable to future program quality systems.
- h. Minimal change activity and minimal depot flight support will be required for future suit programs.

#### 1.4 STUDY APPROACH:

At the conclusion of the Apollo, Skylab and ASTP Suit Contract, NAS 9-6100, key personnel from each of the major functional groups were formed as a study team. The team consisted of representatives from Program Management, Engineering, CMO, Quality and the Business Management groups. Each of the participants was thoroughly familiar with the history and scope of systems utilized by his respective groups. A list of specific study tasks centered around known problem areas were identified as the starting base. Items within this list were assigned priorities in accordance with their potential dollar savings. Second level priorities were established to insure that at least two areas within each discipline were selected for the final list. The list was reduced to 13 specific tasks divided among the five functional areas as follows:

- Program Management (includes CMO, Business Management and Program Control).

- Manufacturing Documentation and Control Systems
  - Improved Configuration Management/Control Methods
  - Government/Contractor Management Reports
  - Program Phasing Philosophy
  - Astronaut Field Option Item Control
  - Business Management System

- Engineering

- Interface Control Documentation
  - Contract End Item Specifications
  - Field Operational Documentation

- Quality

- Traceability
  - Inspection and In-Process Verification
  - Organization

The initial effort of each task consisted of defining the baseline system (Apollo/Skylab A7LB Model Suit) and identifying any cost related problems associated with the baseline system. Flowcharts, standard operating procedures, organization charts, and other pertinent documentation were

used to support this phase. Each individual problem was then analyzed to identify alternate means of optimization. Advantages and disadvantages of each were identified, surveys were made to measure effectiveness of each alternate, and team meetings were used to resolve final selections. Guidelines for future programs were presented for each identified problem area. When implementation of proposed guidelines were in violation of known NASA program requirements, these were identified and proposed requirements deviations were presented. In several cases, the study revealed that some ILC baseline systems did not completely comply with NASA program requirements. These were also identified and where their retention was proposed, supporting evidence of their advantages were given.

Cost effectiveness was measured in each functional group by comparing a baseline organization (A7LB) to a proposed future organization having implemented the suggested guidelines. The individual proposed functional organizations were then combined into a total program organization.

- SECTION II -  
SIGNIFICANT CONCLUSIONS



## 2.0 SIGNIFICANT CONCLUSIONS:

Nine (9) major conclusions or guidelines resulted at the completion of this study. Additional guidelines are also discussed within each of the subsequent sections of this report. These guidelines, if used on future spacesuit programs will result in a major program cost savings.

The major guidelines resulting from this study include:

- a. Place emphasis on the qualification of subassemblies rather than the entire spacesuit assembly.
- b. FACI the first production item rather than the qualification item.
- c. Qualify to the CEI worst case mission requirements the first time.
- d. Reduce the drawing requirements by using manufacturing instructions for configuration control.
- e. Increase component and subassembly acceptance testing to reduce 100% in-process inspection.
- f. Allocate sufficient time early in program to develop efficient systems and procedures.
- g. Perform astronaut fit checks at user's site.
- h. Streamline the data reporting requirements and centralize the data collection system.
- i. Consolidate program management control functions.

Potential cost savings in each study area were reflected in terms of reduced manpower required to operate the respective areas with the new guidelines implemented. These individual groups were then combined into a total program organization. A measure of total potential savings was obtained by comparing this new organization with the one in effect at ILC during the A7LB program. This total potential saving amounted to 1565 man months.

In retrospect, this study stresses the importance of allotting sufficient time early in a program to develop and verify efficient and compatible management systems. Many cost saving innovations to ILC systems were developed and implemented during the Apollo/Skylab programs. The

fact that the contract ended in an "underrun" condition bears tribute to NASA and ILC cost saving efforts. However, during the program, both NASA and ILC became aware of areas that had a potential for being made more cost effective. Several of the conditions discussed in this report are in this category. In the early phases of the program, the limited number of personnel that were technically qualified to analyze and modify the systems were deeply involved in technical and production activities. In the later phases of the program, when qualified manpower was available, a commitment to modify existing management systems would have resulted in a more costly program impact than to continue with the proven operational systems. On future programs, new management systems must be analyzed for cost effectiveness early in the program and existing, proven systems must be utilized where possible.

**SECTION III**  
**PROGRAM MANAGEMENT**

### 3.1 MANUFACTURING/PROGRAM DOCUMENTATION CONTROL

#### OBJECTIVE:

To evaluate the possibility of reducing program costs by elimination of unnecessary drawings and redundant documentation related to the fabrication and control of Contract End Items (CEI).

#### APPROACH:

Identify all drawings and documentation utilized in fabricating the A7LB Spacesuit Assembly. Evaluate the redundancies within the existing documentation and investigate the requirement for possible consolidation of the remaining data. Develop a sample system which could be implemented on future space suit programs and estimate the cost savings which could be realized.

#### PROBLEM:

Contract NAS 9-6100 required generation of drawings per specification MIL-D-1000, Type E, Form B, which in many cases was superfluous to the table of operations (TO's).

#### BACKGROUND:

Federal Sepcification MIL-D-1000, Type E, Form B, states, "Engineering drawings in this category shall provide the necessary design, engineering, manufacturing and quality support information directly or by reference to enable the procurement, without additional design activity of an item that duplicates the physical and performance characteristics of the original design." As a result of this requirement, drawings of all assemblies, sub-assemblies and component parts of the CEI were prepared. This stipulation caused the generation and subsequent updating of 5,250 drawings. 185 drawings were actually required to fabricate an A7LB space suit assembly. The remaining drawings were utilized only as a configuration control vehicle (See Appendix "A") and were prepared to meet the requirements of MIL-D-1000.

It was determined very early in the program that manufacturing personnel could not reliably use softgoods drawings to manufacture softgoods items. Drawings which contained all the detail needed for engineering definition were

so complex and unwieldy that operational personnel could not understand or use them. To resolve this problem, a Table of Operations (TO's) was prepared for each major sub-assembly and assembly. The TO contained all the instructions necessary for the fabrication, inspection and traceability requirements of the CEI. The TO consisted of manufacturing instructions and Fabrication Inspection Route Sheets (FIRS). The Manufacturing instructions remained in the Production area and did not reference any information such as part numbers, sizing information, inspection requirements, etc. The FIRS package, which consisted of approximately 800 pages, was the portion of the TO which contained this information.

Early in the program the TO's and drawings were released for the first CEI (FACI baseline). A dynamic program was encountered as far as configuration changes were concerned, and a dual change control procedure was required - one for the TO's and one for the drawings (see Figure 3.1.1). Any Class I and II changes to one system caused a change in the other. Since different documentation procedures were used by each system, two sets of paper had to be prepared for new designs or changes to existing designs. The TO system was developed through several iterations. These improvements to the system gradually caused the drawings to become increasingly redundant to the TO system. However, the total system drawings and TO's were in existence and being utilized not only at field sites but by other contractors. This situation was allowed to continue as a result of a cost trade-off study which indicated it would be less costly to maintain the inefficiencies rather than implementing a new system.

Upon receipt of a Contract Change Authority (CCA), a design resolution between NASA and the contractor was achieved and a Change Action Request Notice (CARN) was released to authorize revision of the TO's. TO's were classified as Type III documentation and as such did not require the customer's approval. This system permitted the Suit Contractor to make changes to the TO's without awaiting

NASA formal approval of the associated ECO/drawing. This process allowed the contractor to proceed with incorporation of the design change on items in production as soon as was practical to preclude program delays and additional rework or retrofit costs. Concurrent with this effort, a formal Engineering Change Order (ECO) was being generated to revise the drawings. The formal ECO generally followed the CARN by approximately three weeks because of the documentation and approval requirements of MIL-D-1000 and NPC 500-1.

RECOMMENDED GUIDELINES FOR FUTURE PROGRAMS:

It is recommended that the requirements of MIL-D-1000, Type E, Form 3 be revised in future Space Suit Contracts to reference the Table of Operations (TO's) on the major suit assembly drawings and delete the requirement for soft goods sub-assembly drawings. This will eliminate the need to prepare drawings which cannot be used to manufacture and assemble the suit soft goods equipment (patterns and TO's used) and are only needed to satisfy the requirements of MIL-D-1000. This approach will require that the Suit Contractor's Table of Operations (TO's) be used as Type I documentation requiring government approval of revisions and changes. Additional recommendations are discussed in Section 3.2 of this report.

The drawing list for the A7LB Space Suit (Appendix "A") indicates which drawings by size could be deleted. The savings for the preparation of these drawings would be as follows:

	<u>Hours</u>
Drafting	21,274
Mission Support	<u>7,090</u>
TOTAL	28,364 Man Hours

This total savings does not reflect the man hours spent in the updating of the unnecessary drawings.

During the period of September 1969 to September 1970, 210 ECO's were processed to revise 525 drawings. Assuming 50% of these changes affected drawings which could be deleted, a savings of 4,192 man hours could result.

PROBLEM:

Various documentation was generated to verify the configuration of the Contract End Item and to control subsequent engineering changes. This was performed by several different individuals and was not reviewed for possible consolidation of duplicated data.

BACKGROUND:

During the early stages of the Apollo Program, formats for various documentation were generated with the emphasis placed on controlling the configuration and traceability for the manufacture of the FACI baseline space suit assembly. As the program became operational, additional requirements were encountered; such as: retrofit status reports, dash number progression charts, retrofit kit deliveries, etc. New documents were generated and perpetuated by various departments without considering utilizing or modifying existing reports which were being generated by other departments. Once this situation developed, it continued through the Apollo Program. At the end of the Apollo/Skylab Program, over 50 different CMO associated documents were being prepared.

In addition, this system also required initiation of shop orders and compiling of traceability and inspection records on various formats. For each CEI, this meant the processing, duplication and accumulation of thousands of additional sheets of paper. Even with this mass of documentation, the system did not, other than at original release, verify that the operator was using the latest revision of the TO's. As a result, equipment could have been manufactured and assembled from obsolete manufacturing instructions and the error gone undetected until the completion of equipment inspection per the FIRS.

RECOMMENDED GUIDELINE FOR FUTURE PROGRAMS:

Determine as early in the program as is practical which information will be required when the program becomes operational. This information should be funneled to a group which has been delegated authority for all the data

collection and dissemination. A system could then be designed taking all control information into consideration. In addition, all requirements for additional information should be requested through this group to insure optimization of data dissemination. Additional recommendations are discussed in Section 3.2 of this report.



### 3.2 IMPROVED CONFIGURATION MANAGEMENT/CONTROL SYSTEMS

#### OBJECTIVE:

Propose an Authorized Configuration and Traceability System which would consolidate manufacturing, Product Assurance, Program Control and CMO data.

#### APPROACH:

A review of the data requirements of each of the departments was performed. A goal was established to consolidate the following data on a minimum number of formats:

- As-designed vs. As-built Authorized Configuration Classification
- Size
- Qualification Status
- Interchangeability
- Bills of Materials
- Softgoods Sub-Assembly Drawings
- Modification Kit Status
- Traceability
- Delivery Schedule

#### INTRODUCTION:

At the outset of the Apollo program, the configuration controls established were based on a total Pressure Garment Assembly concept, that is an ITLSA, EV Gloves, IV Gloves, Suit Instrumentation, Lunar Boots, and Helmet together formed a space suit assembly. The decision to make the transition to separable component configuration control at the beginning of A7LB 300 series did simplify existing methods. This change caused the removal of certain components from the top assembly (PGA) drawing and components list.

Separable components were defined as those items which collectively comprise a PGA: however, they could be functionally tested and shipped as a separate unit. Although the separable component control created more paperwork, its effectiveness was proven at time of shipment and it caused removal of some details from the top assembly drawing making it easier to use. Each of the components were individually

controlled by part number and corresponding assembly drawing. The ITLSA top assembly drawing for example did not reflect serial numbered effectivities; therefore, a components list - a parts list of critical parts and assemblies, depicting authorized and as-built conditions was initiated to compliment the drawing and Table of Operations (TO's) system. The components list defined the dash number which applied to a given serial numbered suit for each of the ITLSA's. Other separable component configurations (i.e., helmet, gloves, etc.) were controlled by an Authorized Change List (ACL) and/or DD250 identification of the drawing. The ACL identified the components authorized part number and "as built" condition along with a description of each applicable Engineering Change Order. This required ILC configuration management, Quality Assurance, and NASA verification inspection at the time of initial shipment. In other words, the space suit contractor had a mixture of several different types of authoritative configuration and engineering data controlling the configurations of various components of which each had its own unique rules. Also to further define the configuration complexity of the A7LB suit program, there were two distinct categories of ITLSA's; the A7LB 300 and A7LB 600 series applicable to the Apollo and Skylab programs respectively. Both series of suit configurations were based on the same common top assembly drawing. Throughout this A7LB suit period, twenty-three (23) unique configurations ranging from dash 01 through dash 23 evolved from approximately seventy-six (76) Class I engineering changes. In each case, the same top assembly drawing was affected by either creating a new dash number or modifying existing ones. The total number of Integrated Torso Limb Suit Assemblies (ITLSA's) controlled by this drawing during the Apollo/Skylab programs was sixty-seven (67).

This problem is further demonstrated by the earlier Apollo A7L PGA phase where one hundred and fifteen (115) different configurations were created on the same drawing. This resulted in more variation of space suit configurations than the total number of PGA's (96) actually manufactured.

The statistics referenced in this portion of the study reflect the large volume and pyramid effects upon an assembly drawing resulting from multiple engineering changes. The many variations of different configurations on one drawing not only made it difficult for the drawing user to interpret, but also became a time-consuming task when one had to differentiate one configuration from another. A typical top assembly drawing for the ITLSA consisted of four (4) "J" sized drawings supplemented with a list of materials describing one hundred and twenty-two (122) items. This same drawing was revised approximately fifty-two times which included at least one complete redraw. Numerous status listings and matrices also evolved with each engineering drawing change. (Reference Government-Contractor Management Reports Section). These same listings in most cases attempted to serve as drawing abstracts. The end results were always the same with each change . . . a mountain of paper and complicated engineering drawings. Throughout the program the contractor was constantly trying to create one piece of paper that provided a complete description of each separable component configuration.

This was proven to be an impossible task after the generation of more than 50 different CMO reports, matrices, and status listing.

Manufacturing and Product Assurance originated additional documentation for traceability and accountability requirements.

PROBLEM:

Configuration changes occurring at component or lower levels created time consuming paper searches when the identification of configuration differences was required.

BACKGROUND APOLLO/SKYLAB SUIT PROGRAMS:

During the Apollo/Skylab suit program, a form of block configuration control existed but only to the extent where changes were made to "like" items without affecting its top assembly or (part number) identity. An example of this included (9) ITLSA's (serial numbers 001 - 009) which

were configured to an A7LB-100000-01. A Class I Engineering Change Order prescribes a change for all nine suits and the change occurs at a lower level (other than top assembly). The top assembly remains an A7LB-100000-01; however, the changes (or dash 01 modifications) of this sort at any lower level of the top assembly drawing. At time of component shipment (ITLSA for example), if there were five modifications to the dash 01 and only four were incorporated, all configuration data and traceability records would indicate a dash 01 when theoretically it was not. The components list was the only document which indicated the exact as-authorized versus as-built condition of the suit. Furthermore, this list only concerned itself with Class I changes. There were cases of significant Class II engineering changes which were of a Class I nature and should have been reflected at a major drawing level by a part number change but was not. This is not considered good configuration management practice because it created problems of tracking these items, since a Class II change was not required to be recorded on any configuration and/or Quality Assurance data records and yet some Class II ECO's were required to be shown on various reports. Using the nine ITLSA's as an example, if a Class I change was implemented affecting only a portion of the nine suits, then a new dash number was created (-02) for the affected suits. Two unique configurations would now exist, a dash 01 and dash 02 with the possibility of many inherent lower level changes. Multiply this condition by 23 with 76 Class I ECO's and several significant Class II ECO's and it becomes a difficult task to properly identify configuration differences between any combination of dash numbers.

PROBLEM:

No defined policy existed for using acceptable alternate (interchangeable) parts without causing a configuration change.

#### BACKGROUND APOLLO/SKYLAB SUIT PROGRAM:

The definition of interchangeability for the Apollo and Skylab program as stated in the A7LB Pressure Garment Assembly CEI specification prescribed changeout only for those components with the same part number. Each component had to be designed to be replaceable with all other components having the same part number. Each potentially interchangeable part which was a subassembly to a complete component, required a configuration change (or top assembly part number re-identification) prior to implementation. This would involve an ECO to change the affected drawings and configuration data. One of the major difficulties that occurred was the fact that flight qualified hardware remained in a spares category and was not used due to the costly configuration changes that would occur if that hardware was to be used in a suit. As an austerity program was implemented and funding for new hardware (with latest design improvements) was not available, deviations to prescribed practices were accepted. This philosophy was used on the Apollo/Soyuz Test Project where the A7L arm bearing was classified as an acceptable alternate part for the optimum A7LB arm bearing without any configuration impact.

#### GUIDELINES FOR FUTURE PROGRAMS:

Consolidate the information contained on various documentation thus reducing the manpower required and associated costs and still provide sufficient controls and visibility.

As early as possible, a drawing family tree should be generated. The contractor would review and determine which subassembly drawings would be redundant to information in the Table of Operations. The results of this review should be similar to that shown on Appendix "A" of this report. The remaining items which required drawings would be identified by the appropriate model prefix, i.e., A6L, A7LB, etc. Those items not requiring drawings would be identified by the contractor's numbering system.

A follower tag would be generated. The purpose of this document is two-fold:

1. Replace drawings, shop orders, traceability and inspection records and bills of materials.
2. Provide one vehicle to indicate the time required to fabricate the subassembly, which revision of TO for the operation to use, the components required for fabrication and an organized manufacturing flow.

A sample of a format is illustrated in Figure 3.2.1.

An explanation of the form is as follows:

- A. The part number and serial number of this item to be fabricated.
- B. The authority; nomenclature, charge number, spares order, production order go-ahead, etc.
- C. Description - each detail required to complete the assembly would be noted, i.e., join arms to torso, cure, install boots, install wrist disconnect, inspect, etc.
- D. Operation Number: an operation number would be assigned to each detail, for example 005 - join arms to torso, 010 cure, etc. and would identify the appropriate manufacturing or inspection instruction to use for the particular operation.
- E. Accept/Reject/Rework Authority: if the operation is a manufacturing function - the individual completing the detail would initial. In the case of inspection, the inspector would stamp the accept column or note the dispositioning authority, DR, MRB, etc.
- F. Government Acceptance: where applicable the government quality representative would verify inspection.
- G. Hours: scheduled lapse time in hours to complete the task would be noted.
- H. Bill of Materials: all assemblies, subassemblies, piece parts and raw materials required to complete the item being fabricated would be listed.

- I. The part number and nomenclature.
- J. Quantity per unit, quantity per lot - the number and amount of each line item required.
- K. Lot and Serial Number: the material traceability either by serial number or lot number would be verified and noted.
- L. Operation numbers - the operation number or numbers where the line item is utilized would be listed.

The "Follower Tag: could be a Type III document to maintain a fast release system should the program dynamics dictate it. However, this should be the exception. All documentation should be changed by the Procedures of the Engineering Change Order and the class established accordingly.

A control and verification document would also be required. A sample could be an "Authorized Configuration and Delivery Schedule" (ACDS). The purpose of this form would be two-fold:

- 1. The replacement of the following documentation:
  - Components List
  - Authorized Change List
  - Supplemental Change List
  - Component List Progression Chart
  - Configuration Identification Index
  - Configuration Status Listing
  - Open Engineering and Retrofit Report
- 2. Provide a configuration mechanism and qualification status for NASA as well as an active document for all contractor departments.

The ACDS would be initiated at the deliverable CEI level, or could be initiated at an intermediate level as a result of a NASA review of the drawing family tree. All ACDS' would be identified by the model prefixed and would require follower tags and drawings. However, the details on drawings should be kept to a minimum to avoid duplication of information with the TO's. Ideally, they could be outline drawings since the configuration of the components comprising the assembly would be controlled by the ACDS.

A sample of this format is illustrated in Figure 3.2.2. An explanation of the form is as follows:

- A. Drawing number and name.
- B. Custom - identification of the astronaut if the article is custom sized.
- C. Class - indication of classification I, II or III.
- D. Size - in the case of sized parts, i.e., boots, arms, the appropriate size would be noted.
- requires further  
elucidation - what level  
of identification?* → E. List of Materials - the assemblies, subassemblies and piece parts required to assembly the article would be identified by part number.
- F. As-authorized/as-built incorporated - this would show the latest authorized and the present configuration.
- G. Legend - the six categories represent the various situations any given change could be relative to a CEI.
- H. Delivery Schedule - the scheduled ship date for each CEI or modification kit would be indicated.

ACDS would be released upon receipt of a production order go-ahead for only those CEI's authorized. The information required would be compiled from the follower tags and the planning and scheduling section. To indicate how the system would operate, a change cycle will be simulated. (See Figure 3.2.3.)

A CCA is received for an arm assembly. Nine units have been delivered and a Class I change to the lower arm is received to add a pressure relief valve. This change revises the part number of the lower arm assembly from a -01 to -02 with an effectivity of S/N 001, 005, 009 by retrofit and S/N 010 and subsequent "in-line" incorporation. Qualification status is not effected and production order go-ahead has been received for 21 arm assemblies. The contractor changes the lower arm assembly part number (see Figure 3.2.4). The notation AR01 is placed under SN001, 005 and 009 and the delivery date for the modification is listed. This informs the reader that these CEI's are authorized as a -02 configuration, that the present configuration is -01 and the proper delivery date for the modification kit.



When the modification kit is incorporated (see figure 3.2.5) the Symbol A replaces AD01 and the as-built configuration is changed to -02. NA01 is noted under S/N's 002, 003, 004 and 006 through 008 indicating the present configuration and if future program requirements dictate that this change is necessary for any of the CEI's the change may be incorporated without qualification testing. The Symbol A remains under S/N's 010 through 021.

Concurrent with the above, the manufacturing and/or inspection instructions would be modified as necessary and the "follower tag" for the production CEI's would be revised (see Figure 3.2.5) and an explanation is as follows:

Assuming this change affected operation numbers 010 and 015. This would be shown by changing the numbers from 010A and 015A to 010B and 015B. The revision block would be changed to show the new part number of the piece affected, in this case 104002-01 changes to 104002-02 and the pressure relief valve would be added. The only drawing which would be changed is the arm assembly and this revision may only change the part number and revision block and illustrate the addition of the pressure relief valve.



**DR. G. D. D.**

**- AUTHORIZED CONFIGURATION & DELIVERY SCHEDULE -**

Serial No.																							Rev. Date		DNG. NAME	
001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019	020	021	022	023				
																							LEGEND			
																							A - Authorized			
																							XX - Present Config.			
																							AR - Authorized Retrofit			
																							ND - Delivered			
																							XX - Present Config.			
																							QA - Qualified - not Authorized			
																							XX - Present Config.			
																							NQ - Not Qualified or Authorized			
																							(G)			
																							REVISIONS			
																									</	

FIGURE 312.2

**Delivery Schedule**



- AUTHERIZED CATHOLICIZATION &amp; DELIVERY SCHEDULE -

[illegible]

FIGURE 3.2.4





### 3.3 GOVERNMENT - CONTRACTOR MANAGEMENT REPORTS

#### OBJECTIVE:

To consolidate as many Government - Contractor Reports as possible under one control in order to eliminate repetitious activities and data files.

#### APPROACH:

Methods of controlling the quantity of Government - Contractor management documentation used to support the Apollo, Skylab and ASTP programs were examined in addition to new concepts of control. These concepts were evaluated for necessity and cost effectiveness.

Cost savings data was developed by comparing Apollo, Skylab and ASTP programs to the recommended new data centralization techniques.

#### GROUND RULES USED FOR STUDY:

1. The space suit program for the period of 1970 through 1973 was used as the study baseline.

#### INTRODUCTION:

Large quantities of configuration management documentation were prepared during the Apollo, Skylab and ASTP programs. As a result, the duplication of files within the suit program office organizational structure and the preparation of similar reports and documentation by different functional groups occurred. These problems have been examined in this report with recommendations for future suit programs which will result in a cost reduction.

#### PROBLEM:

Duplication of files within the Program Office structure.

#### BACKGROUND:

During the Apollo and Skylab suit programs, several groups within the program office organizational structure prepared, approved and functioned in accordance with similar, and in some cases, the same documentation.



As a result, each group created and maintained their own set of files to perform their duties.

This group organizational structure produced similar and separate files in each of the blocks identified. This section of the systems study, however, only deals with configuration management customer/contractor reports.

It is estimated that there were at least eleven (11) files at the suit contractor's facility containing similarly related data. For each of the separate working data files, additional clerical functions evolved, thereby requiring a large work force to maintain all the data.

Some of the typical management reports, matrices, status listings, etc., investigated included those items listed in Figures 3.3.2.

Many factors contributed towards the generation of separate files at the suit contractor's facility. The reorganization and relocation of various interdepartmental groups throughout the program is considered the prime cause of the generation of separate files. When some of the larger departments within the Apollo/Skylab program structure were divided into smaller groups, the supervision of these new areas adopted their own file keeping. Often the reorganization involved the physical re-location of a department or portion of that department to another area of the plant. When this occurred, the existing files remained with the department head and the relocated activity would generate their own reference file.

One example of file duplication was the records kept for the two governmental agencies located at the contractor's facility; the DCASR and the NASA resident engineer's file. At one time, both agencies shared the same data file; however, when the DCASR personnel were relocated to another part of the contractor's facility, a new file was established.

Another factor which contributed to the duplication of files was the random distribution techniques used for all report dissemination. This method resulted in the originator of various data to establish his own distribution

requirements. Typical random distribution techniques were used with Engineering Memorandums (EM's) and Project Directives (PD's). EM's were the documentation by which technical and contractual data was conveyed to the customer. Since EM's were generated by different management and engineering personnel, each originator established his own internal distribution. PD's served as program management directives to various departments. They contained pertinent suit program instructions not governed by normal change control board directives (CCBD's). The average distribution for a PD during the peak of the Apollo and Skylab programs was approximately thirty (30) in-house copies. In some instances, several people from the same department received copies. This was partially due to the constant change-over of personnel resulting in new oncoming personnel needs. This desire for copies of separate files is prevalent in any industry.

During the latter part of the A7LB suit program, a review of all data and their respective distributions was conducted in an effort to reduce reproduction costs. As a result, a router system was employed. Data distribution listings were reduced by sending copies of data reports to only the head of each department. This effort did ease reproduction costs somewhat; however, it did not stop additional copying of the routed copies.

#### GUIDELINES FOR FUTURE SUIT PROGRAMS:

Proliferation of files and data distribution list occurred during the Apollo and Skylab programs. As a result it is recommended that data centralization and electronic data processing (EDP) be used to enhance data control and will result in a considerable cost savings. A detailed discussion of the recommended electronic data processing (EDP) will be presented in this guideline.

#### PROBLEM:

Similar reports were prepared by the government and the suit contractor and even by different inter-departmental groups.

BACKGROUND:

A problem inherent to the aerospace industry is the duplication of efforts of data management report generation and dissemination by the customer and contractor. Two key factors were the cause of this problem;

1. Uncontrolled paper
2. No central data source

Uncontrolled paper is data which has no formal review and/or concurrence prior to being disseminated.

• Therefore, the data itself is questionable as to its validity. These uncontrolled data usually fostered explanatory or corrective documents after distribution.

The lack of a central data source caused many duplicated reports. Examples include the customer's QA & R personnel favoring the contractor reports and customer CMO personnel favoring their counterparts data. This was a normal occurrence since customer and contractor counterparts understood each other's operations and had difficulty understanding the existence of other operations.

Some examples of similar report generation which existed (shown in combination due to commonality) include:

1. Component Historical Report, Components List, and QA & R Component Serialization Log.
2. Program Action Check List and contents, ARD-001, Mission Profile Matrix, Configuration Status Listing, Waiver Status, Open Engineering and Incorporation Schedule, Flight Readiness Review Package, and Retrofit Status Report.
3. The ARD-004, Engineering Change Log, Drawing Index Card File, and Drawing Status Listing.

These few examples illustrate cases of multiple related reports that evolved over a period of several years. A central data control properly administered could combine the similar data and meet the same data management requirements of the contract by providing fewer consolidated reports.

#### GUIDELINES FOR FUTURE SUIT PROGRAMS:

It is recommended that a data centralization system be used to reduce and as a goal eliminate the preparation of similar data and reports by different contractor and customer groups.

The objectives of a central data source would be as follows:

- A. To monitor and control all data distribution relative to contract needs. This means that once the data requirements and distributions are established, the data control group would control the number of copies reproduced and distributed. Also any requests for additional copies would first have to be approved by the central data office.
- B. To organize the central data source in order to encompass CMO, engineering liaison and administrative service functions. Since the CMO department was essentially the central source of data for the A7LB program, the transition efforts toward complete data control by CMO would be minimal.
- C. To monitor and effect material cost savings in the area of data reproduction. Elimination of "open door" reproduction policies and instituting daily surveillance of Xerox copy counts should discourage in many cases, separate file keeping.
- D. To designate one area as the central point for all current data. Since the central data source either administers and/or generates all data, the status of any data requested from this source will be current.

#### SUPPLEMENTAL RECOMMENDATIONS - ELECTRONIC DATA PROCESSING:

Manual documentation control was used to receive material, manufacture, ship and trace each Contract End Item during the Apollo, Skylab and ASTP programs. Due to the quantity of documentation previously discussed, large data files and continuous updating and referral back to these files became a major activity. As a result, the methods of

Electronic Data Processing (EDP) was investigated during this study. An EDP System is recommended from the time of raw material receipt through the fabrication phases, final shipment, and subsequent QA and R and CMO monitoring.

The common data base approach for EDP is recommended. A common data base approach is a computer oriented central information system which integrates structured data files for use by all operating areas of the contractor. It makes available a set of non-duplicated files which are useable in a timely and accurate manner for both operational and planning purposes.

A chaining technique, which is a data processing technique of tying together files of inter-related data, is used to retrieve information by direct access methods, rather than by traditional sequential methods as was used on the programs generated for the components list, CCA matrix, ARD-001, ARD-004 and COMPHIST data management reports.

The use of this structured information system satisfies the need for information to be current, easily maintainable yet flexible enough to meet the needs of multiple users. Information needed to update the system requires capturing only once, at its source and does not require re-entry for various uses by other operating areas.

One example of a common data base is the use of the ECO system. Figure 3.3.3 illustrates how it was used to support various data generated during the Apollo and Skylab programs. As illustrated in this table, the ECO contained data which was used as the basis for numerous other documentation. Through utilization of the recommended EDP methods, the pertinent information on the ECO would be provided the computerized system.

The proper data inputs of part number, serial number, effectivity, authorizing CCA, and other pertinent data, each cross-referenced to the other will enable easy referral back through the data and provide quick information. If doubt exists with the EDP information, it could then be easily checked with the master record files since the run-off

could reference all documentation used to provide the final output.

Additional information considered to be desirable for future suit programs and obtainable from this EDP program are:

1. An Authorized Component Listing generated by a structured component list expanded for each CEI separable component in the assembly sequence.
2. The Fabrication List (trace data) is a structured list of components (as built) which compares the authorized configuration to that which was built. As configuration differences are recognized, reference to existing CCA records will be noted.
3. Additional traceability is possible in the following manner:
  - a. The ACL Report can be provided by inquiring as to the status of each CCA with respect to its generated ECO's and ECP's
  - b. The common data base facilitates the use of inquiring devices to display the reduction of any assembly to its components or the expansion of any component listing to show the end item structure used or effectivity.
  - c. Vendor traceability and rating techniques could also be implemented when pertinent vendor master files are included into the common data base.

The use of a computer base information system will provide a comprehensive vehicle for timely and accurate data management reporting to serve the customer as well as the contractor's needs.

The concept of EDP control for future suit application is to first reduce the number of reports and matrices and secondly to centralize the data source. The production of accurate reports in a timely fashion, especially during critical times (i.e. flight readiness reviews, actual flight applications, and formal design reviews) will result in a major cost savings. The goal will be to service material

inventory control, configuration control and status listings, production and delivery scheduling, traceability, cost management, and retrofit requirements all from one data source.

In conclusion, this recommendation for EDP control and processing is the result of an investigation to determine the system feasibility for future space suit programs. An additional detailed study involving a systems team, consisting of an analyst and a programmer (approximately nine months) is recommended to completely create and implement the control of all necessary data.

<u>DOCUMENT TITLE</u>	<u>STANDARD DISTRIBUTION</u>
Component Historical Report	12
CCA Matrix	16
Components List (CL)	15
ARD-001	17
ARD-004	3
Program Action Checklist	23
Documentation Section	23
Open Engineering	23
Applicable Mission Open Engineering - Close In Flight	23
Formal Review Status	23
Formal Review Chit or RID Status	23
Engineering Change Log	23
Components List Progression Chart	15
Configuration Change Account Status	6
Mission Profile Matrix	13
Authorized Mission Configuration Matrix (AMCI)	21
Minutes & Agenda Change Control Board Directives (CCBD)	20
CEI/Seperable Component Flight Classification List (Class I, II & III Gear)	6
Configuration Identification Index (CII)	9
Configuration Status List (CSL)	9
Dash Number Progression Chart	11
Waiver Status	10
Waiver Status Log	10
Waiver Status Notice	10
Authorized Change List (ACL)	8
Supplementary Authorized Change List (SACL)	8
Configuration Change Record (CCR)	10
Engineering Change Proposals (ECP)	11
Rough Order of Magnitude	11
Preliminary ECP's (PECP)	11
Engineering Memorandums (EM's)	12 Min.
PGA TLSA Sizing Adjustment Record	As Required
Project Directives	30 Min.
Open Engineering and Incorporation Schedule	14
Equipment Allocation Matrix	12
Flight Readiness Review Package	6
Waiver Deviations	10
Field Operations Bulletins (FOB)	12
FOB Status	12
Systems Safety Notice	12
Field Optional Item List (FOIL)	10
Supplementary FOIL	10
FOI Historical Status	7
Drawing Index Card File (CMO)	As Required
Drawing Status List & ERRC	6
Retrofit Status Report	8
ECO Review	5
ECO Distribution	21



COMMON DATA SOURCE

- ENGINEERING CHANGE ORDER (ECO) -

The ECO provided data for:

Component Historical Report

CCA Matrix

Components List

ARD-001

ARD-004

Program Action Check List

Engineering Change Log

CL Progression Chart

AMCI

CCBD

CII

Dash Number Progression

ACL/SACL

CCR

ECP

FOIL and S/FOIL

Drawing Index

Drawing Status List

Retrofit Status Report

Figure 3.3.3

### 3.4 TITLE:

Program Phasing Philosophy

#### OBJECTIVE:

To reduce overall program costs by minimizing the program impact of engineering changes occurring during Design Verification Testing and Qualification Testing.

#### BACKGROUND:

During the Apollo and Skylab phases of the Space Suit program, schedules were very tight. The program would not allow enough time for the completion of Qualification Testing prior to the start of manufacturing space suits. Changing mission profiles were constantly demanding additional requirements of the suit, which in conjunction with the redesigns to meet the enlarged requirements, caused the qualification testing phase to extend from four months to 15 months on the A7LB space suit.

#### PROBLEM:

Design Verification Testing (DVT) was concurrent with the fabrication of the qualification space suit and Qualification Testing was parallel to the fabrication of production space suits.

The DVT and Qualification Programs were based on the mission requirements of an entire space suit assembly rather than by components.

#### BACKGROUND:

This situation caused significant program delays especially in the initial phases of the DVT and Qualification Testing. If a failure occurred, the entire space suit was "impounded" not only until a design resolution could be formulated, but until design concurrence with the government was reached. Compounding the problem, the delay had a significant cost impact on items being produced that would now require retrofit.

#### RECOMMENDED GUIDELINES FOR FUTURE PROGRAMS:

The DVT and Qualification programs should be based on a component level as depicted in Figure 3.4.1. This would enable the contractor, in the event of a failure, to proceed

to Qualification Testing of another component rather than subject the program to undue delays. It would also allow significant flexibility in the event of unanticipated design problems. Qualification testing could commence with a slave component until the item is ready for design release.

The required cycle life of each component, arms, legs, etc. should be established early in the program to insure DVT and Qualification procedures are written to insure that this flexibility is reflected and approved.

PROBLEM:

The design engineers could not adequately train the project, manufacturing and quality engineers prior to fabrication of the DVT space suit.

"Fine tuning" changes were incorporated in the DVT and qualification units without "cost trade-off" studies.

Future programs should be designed to permit design engineering to allocate sufficient training time for project, manufacturing and quality engineers. The results of this situation cause the design engineer to spend an excess amount of time supporting manufacturing problems rather than solving known design tasks. The design engineer exerts a considerable amount of influence during the fabrication of the DVT and qualification units. Since his goal is to provide the best design within the allotted time, "fine tuning" changes are incorporated. These changes could very often be incorporated in any one unit, but to process the formal change paperwork and to coordinate the redesign to meet production schedules often caused schedule delays. Verifying the configuration at Pre-delivery Acceptance was very time consuming, this factor contributed significantly to that problem.

RECOMMENDED GUIDELINES FOR FUTURE PROGRAMS:

The appropriate engineering disciplines and program management should control the fabrication of all contract end items. This can only occur if these groups are available and sufficient time allocated prior to any fabrication.

PROBLEM:

Significant delays are encountered during Qualification testing awaiting contract changes authorizing incorporation of design changes.

BACKGROUND:

FACI was performed on the first qualification space suit. This signified that the CEI met the design requirements of the drawings. However, one of the main problems was the time delay from submittal of ROM to receipt of CCA. The ECP baseline for changes is established at FACI. Thus, this delay occurred during the qualification of the PGA's. This caused significant program delays and associated increases in program costs.

GUIDELINES FOR FUTURE PROGRAMS:

Depending on the circumstances and negotiations, the contractor could commit to a FACI after completion of Qualification and a summary FACI upon availability of the final component. This agreement would place additional emphasis on the contractor during the design phase to assure successful completion of Qualification. However, such areas as NASA approval of changes, duration of the development phase, etc. would require re-evaluation.



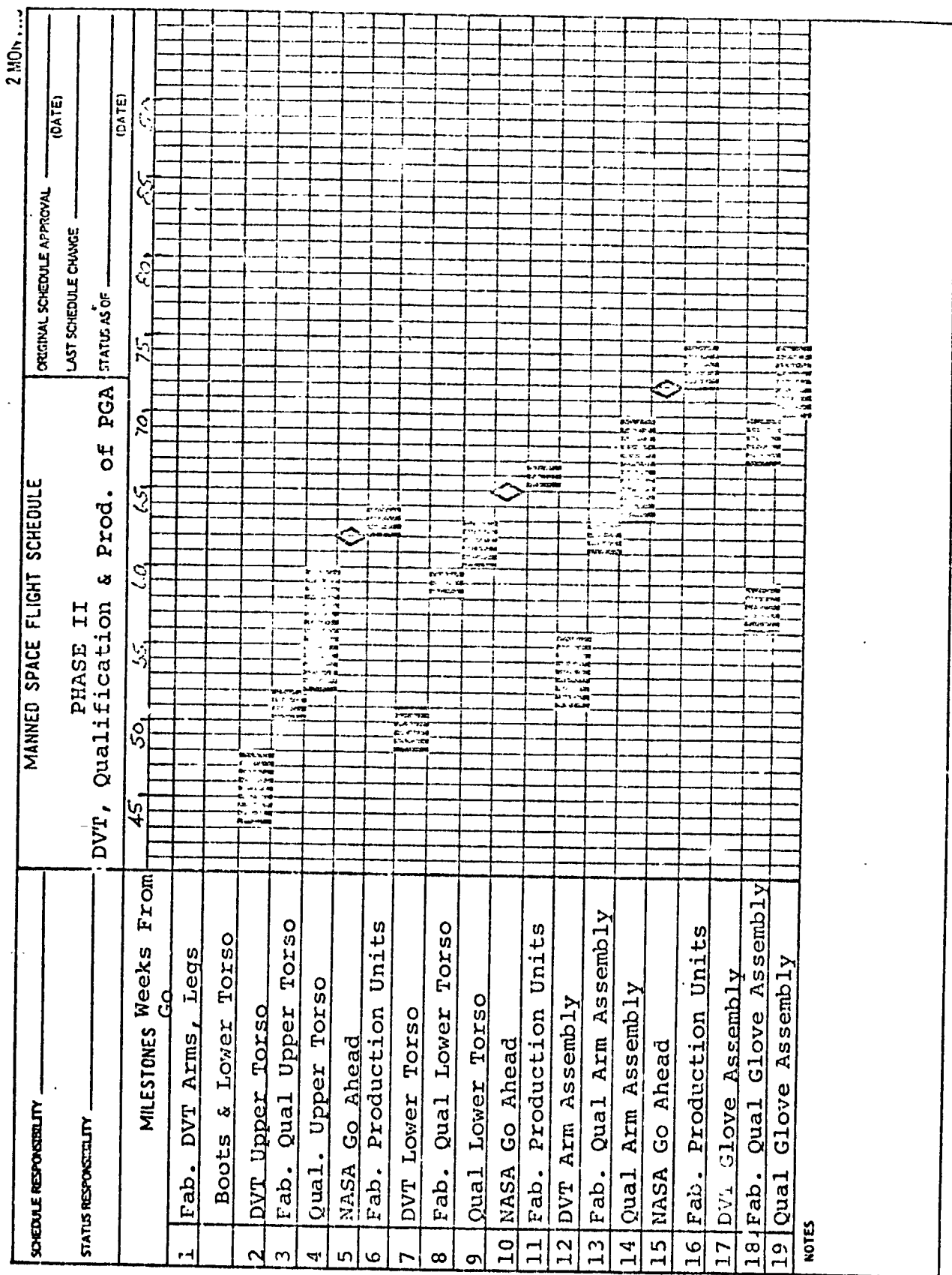


FIGURE 3.4.1

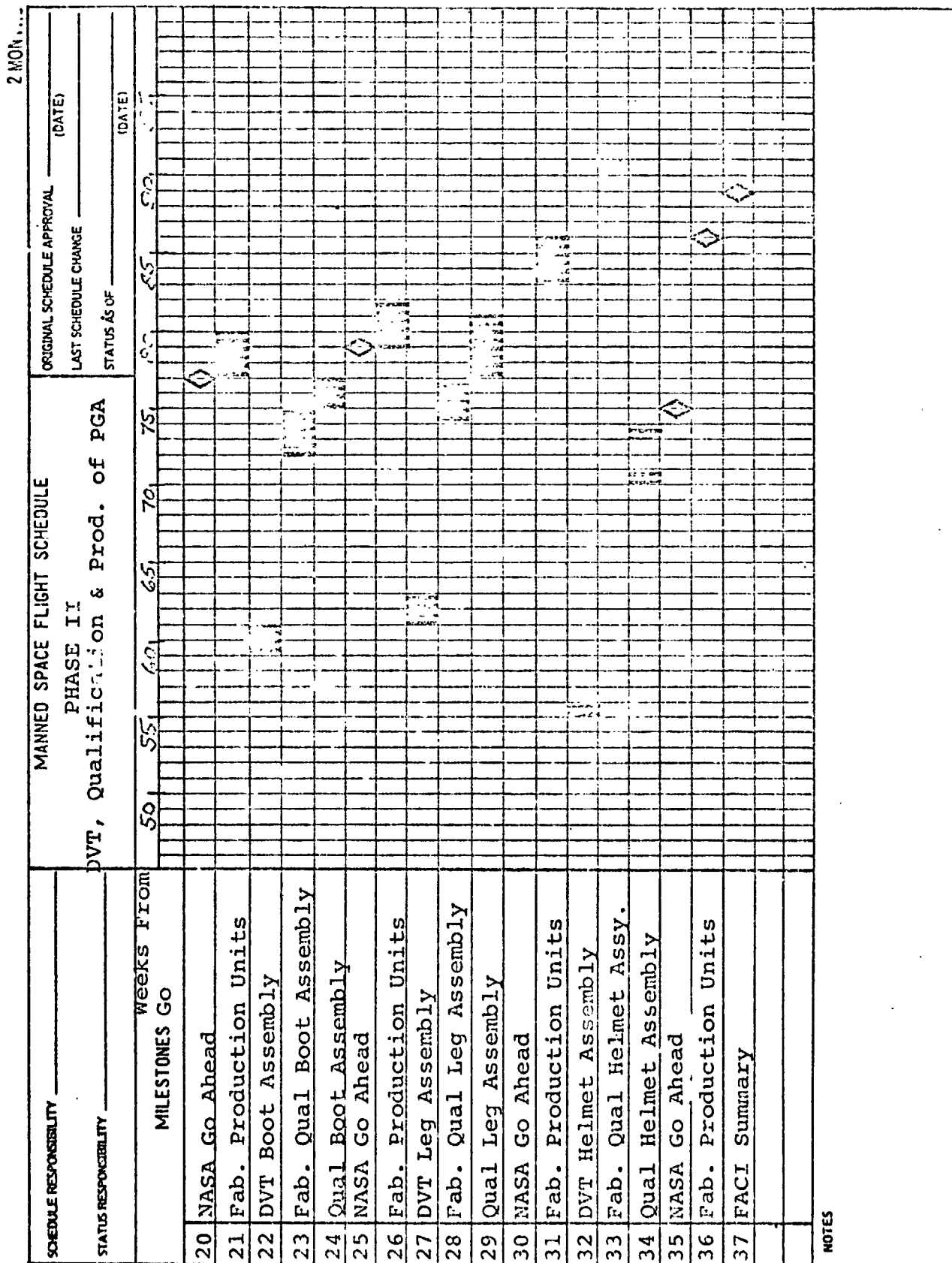


FIGURE 3.4.1

### 3.5 TITLE:

Astronaut Field Optional Item Control

#### OBJECTIVE:

To establish sound guidelines for field optional item control which will result in cost saving for future suit program.

#### PROBLEM:

Field optional modifications which impact configuration change, multiple drawing revisions, additional tracking mechanisms, and generation of massive historical files.

#### BACKGROUND APOLLO/SKYLAB SUIT PROGRAMS:

Many field optional items (FOI's) evolved during the 200 plus fit checks of contract NAS 9-6100. The FOI's usually resulted when a crewman at initial fit check would request modifications to his suit or separable component for some of the following reasons; physical abnormalities, personal discomfort caused by hard points on the suit, cosmetic value, simplification of donning and doffing, etc. The approximate number of defined FOI's that were initiated at fit checks, and controlled and monitored by the CMO department during the suit program was thirty (30). This count includes separate listings of FOI's for each of the separable components of a PGA; ITLSA, IV/EV Gloves, helmet, suit instrumentation, and CEI Liquid Cooling Garment.

During the earlier part of the program, there were no real controls governing the creation and implementation of FOI's. The definition of FOI's (originally referred to as crew preference items) were ambiguous in that the notation for various FOI's or comfort pads usually indicated "install as required". A system of FOI controls was then established to properly identify and control (in detail) all new and/or revised items. Each time a crewman expressed a desire for a unique modification to his suit, this request was first exposed to the customer prior to incorporation.

It was the contractor's responsibility to relay this request to NASA via notation on the affected components shipping papers, the Form DD250. After the request for the



or new FOI was approved by NASA, and contractual authorization granted, the following chain of events occurred:

1. CMO initiation of configuration change control board directive, specification change notice, and subsequent Engineering Change Order.
2. Revision to applicable drawing affected by adding or revising a Field Optional Item to an end item and/or separable component. One typical example causing a configuration change could be the addition of a new unique comfort pad on the torso limb suit liner assembly for Skylab only. This would involve a change to the liner assembly drawing, creation of a comfort pad drawing and part number change at the top ITLSA assembly.
3. CMO updates master Field Optional Item List (FOIL) and initiates a supplementary FOIL for all suits affected that have been DD250'd. The new FOI requirement would be scheduled for retrofit after consulting the crewman to see if he desires the new change.
4. The insertion and verification of the new FOI requirement in applicable component acceptance data package.

Although a formal list of FOI's were described in the PGA Contract End Item Specification and were similar in nature, each separate category of suit configurations required unique configuration requirements. Incorporation and configuration of FOI's for Skylab differed from the Apollo suit program. One example would be the orientation of gas connectors where the crewman had the option of positioning the "lock-locks" in the orientation most comfortable to him when attaching O<sub>2</sub> and exhaust lines. This item was noted in the CEI specification as "orientation of gas connector locks" for all Apollo, Skylab and ASTP suits. This particular FOI required different clocking configurations for the Command Module Pilot as compared to clocking for the

EV crewman's suits since the gas connector locations on the PGA's were different.

The specific tasks involved in the preparation for a forthcoming fit check and subsequent fit check action was as follows:

Crewman Initial (First Suit) Fit Check.

1. Preparation of a total FOI package showing all the various options for the separable components and CEI's to be fitchecked. This package is submitted to the Fit Check Engineer the day before fit check.
2. The Fit Check Engineer discusses the various field optional items with the crewman at fit check using the FOIL as a guidelines.
3. The crewman's FOI selections are noted on the FOIL package and returned to the CMO.
4. CMO generates a Fit Check Project Directive which directs the details for fabrication and incorporation of the various crewman selected options. This action is conducted prior to the shipment of the CEI/separable components affected.
5. After the FOI's are incorporated, Quality Assurance submits a verified FOIL to the CMO for close out. If a requested FOI does not get incorporated at the depot, then CMO annotates this configuration difference on the separable components/CEI's parts list or ACL which ever is applicable.
6. If a request for a FOI is made that was not defined in the CEI specification, CMO would then initiate paperwork to advise the customer of a new request. Approval of this new request for a FOI would revert back to the chain of events described in the previously mentioned Items 1 - 4.

Crewman Subsequent Fit Check (Second and Sub Suits)

1. About 4-5 weeks prior to the next forthcoming fit check, CMO would initiate a FOIL package (with Fit Check Engineering, Program Control, CMO, QA & R, and Manufacturing review) to manufacturing

for incorporation of all FOI's previously requested by the same crewman. This was done to have the crewman's next production suit to be identical to that previously shipped.

2. After incorporation of prescribed FOI's, Quality Assurance would advise CMO as to the results of manufacturing's efforts. If a FOI did not get incorporated by manufacturing due to schedule problems, then the CMO would advise Fit Check Engineering of any discrepancies.
3. The Fit Check Engineer would advise the crewman of the options incorporated/not incorporated during the suit's fabrication phase. At this point, the crewman had some suit experience on his first suit and usually as was the case, he would not want some of the options requested during the initial Fit Check. The next step would be to remove these FOI's not desired and reflect all new desires on any subsequent Fit Checks. Therefore, the FOI baseline for each crewman varied with each of his suits.
4. Results of the second suit fit would be received by the CMO and appropriate action taken to repeat the previously mentioned steps one through six.

A new problem surfaced when suits were undergoing numerous rework operations at the depot and field sites. The rework in some instances caused the alteration or removal of certain FOI's, citing the arm and leg adjustment changes as a typical example.

This problem wouldn't show until the next time the crewman wore the suit. This condition not only produced crewman discomfort, but caused a loss of confidence over the field optional item configuration and quality controls. To counteract this type of problem, the CMO was tasked to review each CEI/separable component ADP upon receipt at the depot prior to rework. CMO compared the original baseline

FOIL to the verified FOIL in the ADP. All differences and unique changes derived from the ADP were noted on a FOI Test Preparation Sheet. It was CMO's responsibility to identify the exact dimensions, comfort pad requirements, gas connector clocking, etc., on the TPS. Upon completion of retrofit requirements, CMO with the aid of the Quality Assurance Department, re-verified the fact that the suit was restored to its original FOI status prior to re-shipment. The efforts involved by the CMO during this period amounted to a full-time task during periods of consecutive fit checks. Also all field incorporated FOI's before they were incorporated had to be reported to the CMO, who in turn reviews same with depot project engineering. The change receives depot concurrence and is authorized for incorporation by the applicable field site. Verification of this incorporated change is then logged in and monitored by the CMO.

There were many FOI's that, regardless of whether or not the crewman desired same, were shipped with each suit. The FOI shipments with each CEI/separable component produced additional configuration and Quality Assurance controls. For each CEI/separable component, there were standard FOI's, i.e., chin pad, suit liner comfort pads, wristlets, glove comfort pads, valsalva device, etc.

The rules for FOI's were changing due to program dynamics. This induced another problem of whether or not to re-identify the component for new proposed FOI's or add the change across the board for all suits.

The latter preference was usually the rule, and "mountains" of paperwork were generated by new ACL's, ECO's, Drawing Changes, Specification Changes, FOIL revision, etc. One of the rules applicable to FOI re-identification of the "as-built" part number on a components list to agree with the "authorized" part number was when a crewman exercised his option to install/not install the FOI. This meant that if he did not want a certain FOI that affected a dash number change, and was noted on the FOIL, the "as-built" dash number was progressed indicating incorporation.

By looking at the components list you could not determine whether or not the change actually was installed, but only that the crewman exercised a positive or negative option.

It was obvious that due to this complex system of Field Optional Item identification, control, and continuous accountability that a more practical and economical system could be devised. Below are some recommendations for enhancing previous FOI methods and controls.

PROPOSED FUTURE SUIT PROGRAM METHOD:

Recommendations for future program FOI control should follow these guidelines:

1. Conduct all fit checks in the field; this permits the re-verification of field optional items with the crewman upon completion of FOI installation.
2. Install all FOI's in the field. This action would eliminate FOI reporting to the depot, as well as allow the crewman to better evaluate the effects of the FOI. In most cases, the temporary installation of comfort pads and subsequent acceptance by the crewman would save many manufacturing, CMO and Quality Assurance hours.
3. Do not change configurations as a result of new or revised FOI's. If a crewman's desire for change affects the qualification status of a CEI or separable component, then it should be classified as a Class I engineering change which requires contractual authorization.
4. Create a "cookbook" of acceptable FOI's as defined at the CEI/Separable component FACI. This proposed "cookbook" would be classified as a Type II document. It would be subjected to internal ECO controls; however, at the Class II level of change. This same book would define in detail each change, all necessary manufacturing and fabrication instructions for installation, methods of tracking, and the procedures involved with each fit check operation. This book would

eliminate the need for the CEI specification FOI listing, and numerous activities conducted by the CMO. Verification of FOI installation should remain a part of the end item ADP.

5. Provide FOI's only when specifically requested by the crewman.

It is estimated that a minimum of 40 hours was expended by CMO for each fit check. The cost savings experienced under the new method relative to the CMO effort would be approximately 36 hours/fit check.

### 3.6 TITLE:

#### Business Management System

### PROBLEM:

During the performance of NAS 9-6100 the two most significant problems encountered in the operation of the business management system were:

1. The 533 reporting format was not directly relatable to ILC internal cost control methods. This rendered the 533 significantly non-utilitarian as an internal management tool. This resulted in the construction and administration of a redundant cost control system, non-reflective of the 533 report, to provide ILC management with cost and manpower monitoring data.
2. The Work Breakdown Structure (WBS) which served as the basic skeleton for reporting (533 report) and for developing cost collection data went through significant changes at various stages of the contract. At each change, implementation and re-education produced inefficiencies and inaccuracies as well as a loss in continuous track of data. Equally as important, the various WBS's employed did not provide significant segregation of data to establish meaningful relationship for management information relative to future planning efforts.

### BACKGROUND:

#### WORK BREAKDOWN STRUCTURE:

At the outset of NAS 9-6100, Schedules I and II, a WBS was employed which closely approximated the classic type WBS found in textbook applications. A facsimile of the WBS is shown in Figure 3.6.1. This WBS provided information adequate to meet program reporting requirements during the period it was applied. The reports, however, never served as an internal management tool. The data available from this WBS has blended in quite satisfactorily with the general

terms established in the previous section's historical cost analysis. The failings in this WBS are that a Contractor must be sufficiently computerized and oriented towards government cost systems as well as being properly organized to attain the full benefits of this application. The cross-matrixing of organizational and resource information becomes quite cumbersome to handle and useful timely data is difficult to derive without correct orientation and adequate computer systems. This WBS concept was abandoned at the inception of Schedule IV.

Schedule IVA was performed under the WBS shown in Figure 3.6.2. This WBS was constructed to provide separation of all engineering and manufacturing costs by Contract End Item (CEI) and Level 1 Tasks; i.e., Design, Component Development, Production, Spares, etc. Program Management and Field Support were exceptions. Costs were further segmented by functions. The management philosophy at this time was that all costs should be identified to a CEI within a Level 1 Task. In retrospect, the data in this form was never used or compiled to produce meaningful management information. The functions which were determined to be essential data at the time of formation of the WBS have had limited value in historical cost studies and were not useful in any way to ILC in the day-to-day operation of the program. The use of this data by NASA is not known.

At a milestone occurring on July 1, 1971 and following negotiations of SA 433 a revised WBS was instituted. This was the start date for Schedule IVB. This WBS attempted to retain the Level I Tasks for continuity. The primary aim, however, was to relate the framework as close as possible to the organizational alignment of ILC. This was significant in that negotiated manpower and internal budgets had been arranged organizationally. It was felt then, and now, that a basic framework should be established early and retained from proposal phase through negotiation and into operation and reporting of the program. This WBS concept was retained essentially through the completion of



the program. One notable change that did occur was the establishment of Mission Support as a Level 1 Task at January 1, 1973. This was another step closer to adhering to negotiated and budgeted information. Previously Mission Support had been included in various Level 1 Tasks.

Reviewing all the WBS's employed during the performance of Schedule IV, very few items are found which were continued and retained in the same form and under the same ground rules throughout the program. In addition to the WBS levels varying it is also noted that the other axis to the WBS, the resources applied, varied in its format and content through the program. In Schedule I and II labor categories were the detail level of the WBS. In Schedule IV, functions were the detail level. Neither of these, in the application at ILC, provided workable management data for day-to-day program monitoring nor did they readily produce data useful for the historical cost analysis in the previous section.

The WBS's themselves were not sufficiently detailed to provide ease in interpreting and applying. WBS element descriptions and ground rules seemed continually to need reclarification. This undoubtedly was caused by the instability in the WBS's but equally resulted from "gray area" in each WBS. Future WBS's should be clearly defined and be aligned such that "gray areas" cannot exist.

#### 533 REPORT:

Reporting of data via the 533 Report was strictly an exercise in report preparation. Very few facets of the 533 data were relevant to internal management of the program. Rather than the report data being a natural fallout from the daily business information it was a once-a-month reconstruction. It was necessary to take input data from the departments involved and reorient the data for inclusion in the report. This reorienting of data coupled with the volume of inputs and the lack of computer facilities placed significant burdens on manpower. Both parties, the government and the contractor, would be better served if the organizational

alignment and the cost systems in place at the contractor's facility were governing factors in the establishment of 533 reporting formats. This problem, however, is relatable to the formation of the correct WBS. The solution of the correct WBS should also produce the solution to the 533 reporting problems.

#### GUIDELINES - FUTURE PROGRAM RECOMMENDATIONS:

At the close of the Apollo Program, NAS 9-6100, the cost studies presented in the previous sections were performed. Prior to the study, the significant criteria to a suit program were determined. The major functions of Development, Production, Mission Support, Program Management, Spares, Retrofit and Repair, and Field Support were established as being the meaningful criteria which would be existent in typical suit programs. These functions should therefore be the basis for management of future suit programs. The Work Breakdown Structure (WBS), being the skeleton for the business management system, should be constructed to produce information on the major functions described above. Exhibit i is a recommended WBS which would be applicable to typical space suit programs and which also would provide the segregation of cost into the major functions. A brief description of each major function and the recommended contents of each are as follows:

Program Management - Level 1 task Program Management would include costs associated with activities performed by all segments of the program office organization.

Development - Level 1 tasks Design, Component Development and Engineering Tasks would combine to encompass the total Development function.

Design - would include all engineering and other support effort such as quality assurance and reliability and the fabrication of engineering models for verification of design concepts. Individual cost accounts could be established at Level 2 to segregate costs of each design activity.

Component Development - would include fabrication of formal Design Verification Test prototypes and Qualification Test units. Formal Design Verification Testing and Qualification Testing would also be Level 2 activities within this task.

Engineering Tasks - would accumulate costs on all Engineering Design tasks authorized by Work Request Forms (WRF's).

Individual cost accounts would be assigned to each WRF.

PRODUCTION - All production costs would be included under the Level 1 task Production. Production would be defined as including only that manufacturing and inspection labor directly associated with fabrication of the Contract End Items. Manufacturing Engineering would also be considered as a production cost. Level 2 task CEI's would be further segregated at Level 3 into the various CEI's determined to be separately identifiable on the future space suit.

MISSION SUPPORT - All costs associated with effort performed by personnel designated as mission support personnel shall be included. Mission support personnel would perform engineering, quality assurance and reliability activities.

RETROFIT AND REPAIR - This Level 1 task will segregate at Level 2 into the following:

Depot Retrofit - all retrofit work performed on articles already delivered to the customer but retained or returned to the contractor's depot would be considered as depot retrofit. Individual tasks could be assigned for each retrofit task.

Modification Kit Fabrication - all costs associated with M & R effort authorized by WRF's would be accumulated under this Level 2 task.

SPARES - all spares costs would be included within the single Level 1 task entitled Spares. All manufacturing and inspection labor and materials utilized in the completion of spares orders would be included. Each Spares Order would have an individual cost collection code.

FIELD SUPPORT - the Level 1 task Field Support would be totally synonymous with the function Field Support. All costs associated with the support of the space suits in the field would be included. Level 2 segregation could be by site with Level 3 if desired further segregating the types of field support activity.

In further review of the meaningful criteria to a program as well as reviewing the needs of a contractor for internal management of costs, it was decided that the typical space suit contractor would be organized into the following primary labor divisions: Program Management, Engineering, Manufacturing, Quality Assurance and Reliability, and Field Support. This being the case, detail level labor should be summarized accordingly. Organization coding to provide this data could be established. Exhibit 1 portrays a typical organization summary which would be used in adjunct to the WBS and serve as the detail level of the WBS. Brief definitions follow:

Program Management - Each organization under the Program Office would have an individual coding. The sum of the data accumulated through these codes would represent the total activity of the Program Management organization.

Engineering - Engineering could be further segmented into such alignments as Systems Engineering, Design Engineering, Test Engineering or as seen fit by the organization at the time of performance.

Manufacturing - The Manufacturing organization would segregate and identify at a minimum all activity performed by the fabrication group; the inspection group and manufacturing engineering.

Quality Assurance and Reliability - The QA & R organization would include such groupings as Quality Engineering, Reliability Engineering, Technician Support and Documentation Support. Other organizational alignments deemed more satisfactory at the time of contract performance could be inserted here as well as in all other primary labor divisions.

Field Operations - Each Field Site would be the basis for segregation of organizational information for field operations. The above recommendations are directed towards specific areas needing attention at the outset of the next suit program. In addition to the above, however, there are some general recommendations which should definitely be

included in the planning for the next program. They are:

1. Establish a WBS, preferably along the lines described above, early in the program; be sure it will meet all needs of the business management system; and that it will be in concurrence or readily adaptable to the contractor's internal accounting system; then retain the same WBS through the entire program.
2. Make the reporting system a useful tool to both the contractor and NASA. Do not require establishment of information tracks that are not readily drawn from contractor data or have no use to the contractor's management system.
3. When the WBS is finally solidified, establish clear guidelines to the application . . . allow no gray areas. Do not change ground rules in mid-program.

The above recommendations are in some cases general in nature and in others, more specific. In either case, however, we feel that they will be of benefit in the establishment, operation and analysis of future space suit programs.

Apollo  
NAS 9-6100 Schedules I & II  
Work Breakdown Structure

Level

0      1      2      3

---

Schedule I

Contract End Items

PGA

LCG

TMG

EV Visor

Garment Accessories

Program Management

Project Engineering

Systems Integration

Manufacturing Engineering

Quality Assurance and Reliability

Schedule II

Sustaining Engineering

Field Support

Off Site

On Site

Spares

Spares Program Management

Spares Orders

FIGURE 3.6.1

APOLLO SCHEDULE IV  
COST COLLECTION LISTINGS

21. OCTOBER 1970

***** LEVEL 1 *****		
819	PROGRAM MANAGEMENT	
820	DESIGN (CON'S)	
821	CONTRACT MANAGEMENT, QUALIFICATION	
822	PRODUCTION (SUITS & AUXILIARY EQUIPMENT)	
823	ENGINEERING TASKS (MIL)	
824	IN-PLANT SUPPORT	
825	SPARE PARTS	
826	PRODUCT SUPPORT	
827	IN-HOUSE REPAIR & MAINTENANCE	
828	WFO ENGINEERING SUPPORT	
829	LIGHTWEIGHT IV SUIT (SHUTTLE SUIT)	
***** LEVEL 2 *****		
* SYSTEM MANAGEMENT *		
X01	MANAGEMENT	
X02	PROGRAM PLANNING & SCHEDULING	
X03	COST & MANPOWER ANALYSIS	
X04	CONTRACT ADMINISTRATION	
X05	SYSTEMS SAFETY	
X06	CONFIGURATION MANAGEMENT	
X07	PROPOSALS & ESTIMATING	
X08	TECHNICAL PUBLICATIONS	
X09	SUMMARY ACCOUNT	
* PRODUCT SUPPORT *		
X30	DOVER OPERATIONS	
X31	MSC FIELD OPERATIONS	
X32	KSC FIELD OPERATIONS	
X33	MSC SUPPORT	
X34	LANGLEY SUPPORT	
* CEF'S *		
X51	A7LB/A7L PGA	
X52	LCG	
X53	LWA	
X54	FCS	
X55	1M HELMET STORAGE BAG	
X56	ECU MAINTENANCE KIT	
X57	HELMET SHIELD	
X58	CMV ELECTRICAL HARNESS	
X59	URKE VALVE	
X60	SIP ELECTRICAL HARNESS	
X61	L/G ADAPTER	
X62	LIGHTWEIGHT IV SUIT (SHUTTLE SUIT)	
* SEPARABLE COMPONENTS *		
X70	ITLSA-IV (CMP)	
X71	ITLSA-EV	
X72	HELMET	
X73	IV GLOVES	
X74	EV GLOVES	
X75	LUNAR BOOTS	
X76	ELECTRICAL HARNESS	
X77	BIO-HARNESS	
***** LEVEL 3 *****		
X0X	ALL TASKS OTHER THAN PRODUCT SUPPORT	
* PRODUCT SUPPORT *		
X1X	MANAGEMENT	
X2X	FIELD MODIFICATION/MAINTENANCE & REPAIR	
X3X	SPARE PARTS & MATERIAL IDENTIFICATION & ACCOUNTABILITY	
X4X	CREW MISSION SUPPORT	
X5X	ENGINEERING SUPPORT	
X6X	MSC TEST SUPPORT	
X7X	ZERO "G" A/HF/SUPPORT	
X8X	ADVANCED PROGRAM SUPPORT	
X9X	APOLLO APPLICATIONS SUPPORT	
***** LEVEL 4 *****		
* FUNCTIONS *		
XX1	ADMINISTRATION	
XX2	ENGINEERING	
XX3	QUALITY ASSURANCE	
XX4	INSPECTION	
XX5	FABRICATION	
XX6	ASSEMBLY	
XX7	TESTING	
XX8	TOOLING	
XX9	FIELD SUIT TECHNICIAN	
XX0	RELIABILITY	
XX1	MATERIAL	
XX5	SUBCONTRACTING	
XXC	CONTRACT LABOR	
XXT	TRAVEL	
XXA	OTHER DIRECT	

FIGURE 3.6.2



## GLOSSARY

COST ELEMENT - the type of cost, e.g., Labor, Material, Burden, etc.

MAJOR FUNCTION - a separation of costs into meaningful generic tasks typical of suit programs. The functions are: Production, Development, Mission Support, Program Management, Field Support, Maintenance and Repair, and Spares.

PHASE - refers to the various suit applications and time divisions of the total contract relative to Apollo 7 through 14, Apollo 15 through 17, Skylab and ASTP.

PRIMARY LABOR DIVISION - a separation of labor into organizational components, i.e., Manufacturing, Engineering, Program Management, Quality Assurance, and Reliability and Field Support.

### 3.7 TITLE:

Program Management Organization and Manpower Summary

#### OBJECTIVE:

Evaluate the program management organization which existed during the Apollo, Skylab and ASTP suit programs. Determine the total manpower savings resulting from the implementation of the guidelines for future programs as presented in paragraphs 3.1 through 3.6 of this section.

#### APPROACH:

The ILC program management organization which supported the Apollo, Skylab and ASTP suit programs was used as a comparative baseline. Guidelines identified as program management manpower savings in paragraphs 3.1 through 3.6 of this section were used to formulate the recommended manpower required to support a future suit program. The resulting summary of manpower savings was then determined by a comparison of these program management organizations.

#### GROUND RULES USED FOR THE STUDY:

1. The program management organization for the period of 1970 through 1973 was used as the study baseline. Emphasis was placed on reducing the level of required manpower.
2. The proposed program management organization was manloaded to support the program schedule presented in Section 3.4

#### DISCUSSION:

Implementation of the guidelines for future programs as discussed in the preceding paragraphs of this section resulted in the recommended program management structure as illustrated in figure 3.7.2. The manpower level of this organization was then compared to the level of the program management organization that existed at ILC during the period 1970 to 1973 (See Figure 3.7.3). The manloading of the 1970 to 1973 organization was based on an average 1/5 production rate. In order to properly compare these organizations, the production rate was factored to reflect the estimated levels of manpower required for a 1/20


production rate. Comparison of these two programs revealed a total manpower savings of 480 man months.

**A7LB PROGRAM**  
**FUTURE SUIT PROGRAM**

DEVELOP. 

DVT 

FAB. QUAL 

QUAL 

PRODUCT. 

APOLLO/SL/ASTP YEAR	1970			1971			1972			1973		
	1	2	3	4	1	2	3	4	1	2	3	4
QUARTER	1	2	3	4	1	2	3	4	1	2	3	4
LEVEL FACTORED FOR 1/20	174	174	174	174	141	141	141	108	97	87	87	72

FUTURE PROGRAM

YEAR	1ST				2ND				3RD				4TH			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
QUARTER	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
PROPOSED LEVEL	138	138	138	138	96	87	72	72	72	72	72	72	54	54	54	54
NET REDUCT.	36	36	36	36	45	54	69	36	15	15	15	15	18	18	18	18

PROGRAM OFFICE MAN-MONTH SUMMARY  
 (EXCLUDING PROJECT ENGR. & PRODUCT ASSURANCE)

REDUCTION - 480 M/M  
 FIGURE 3.7.1

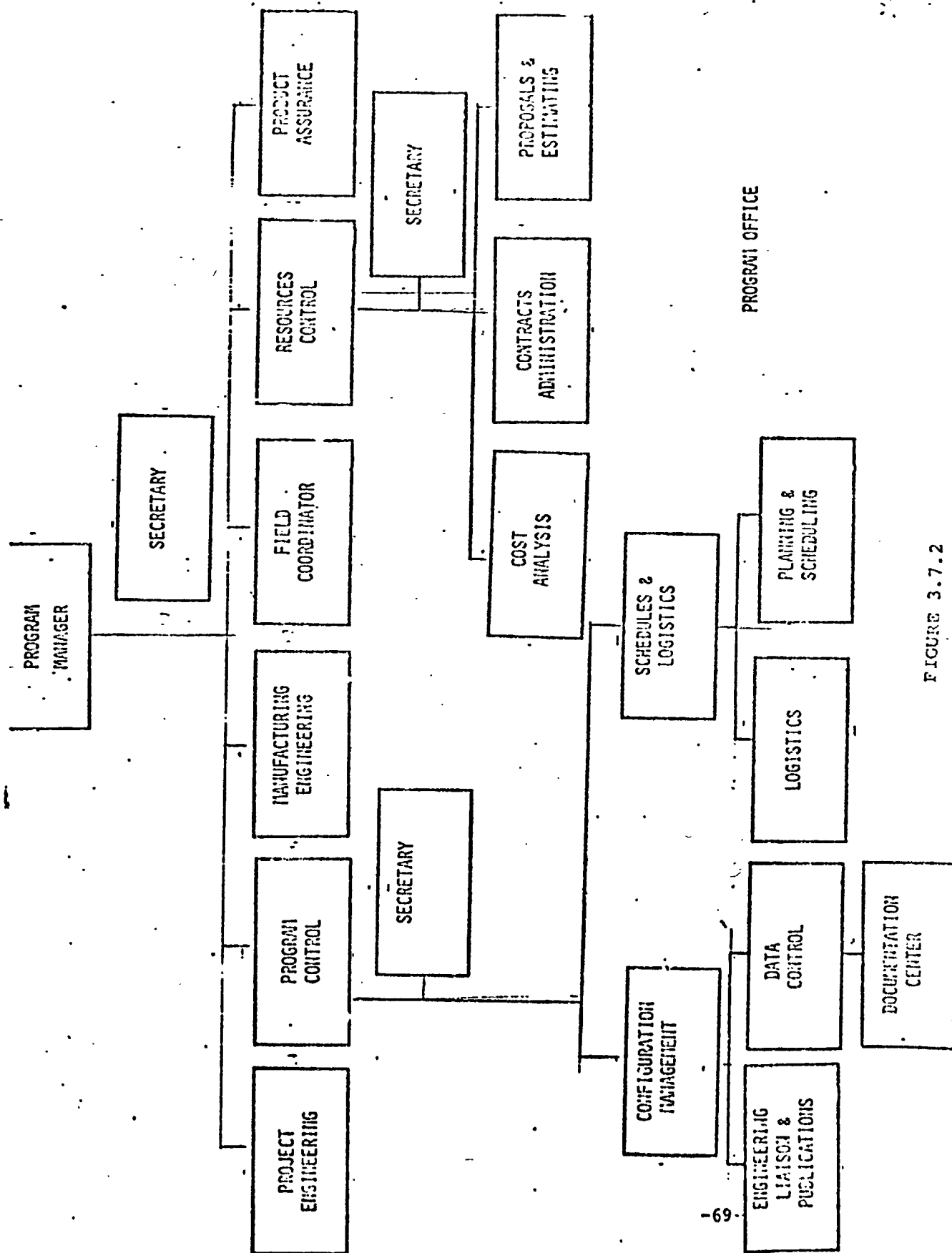


FIGURE 3.7.2

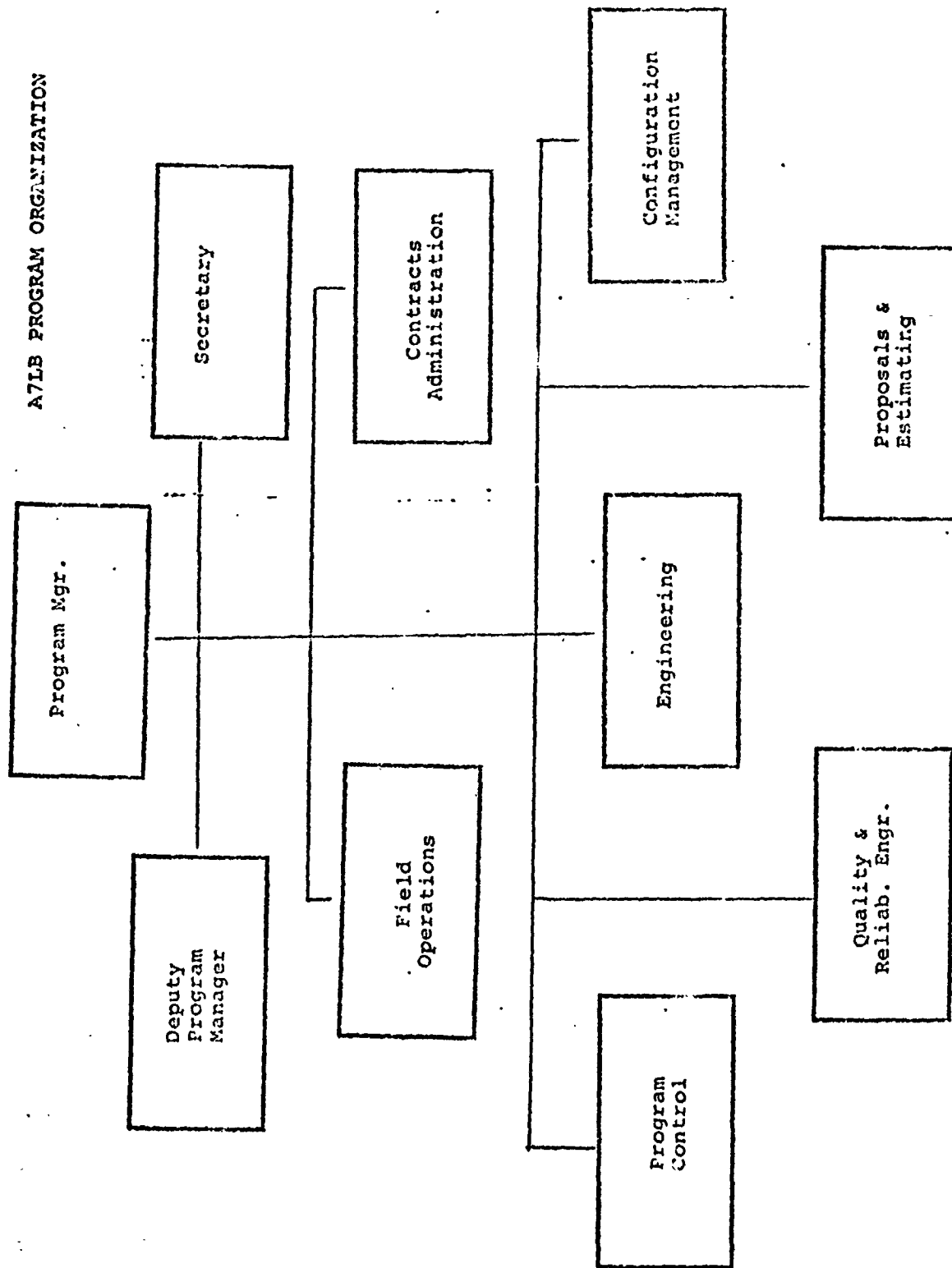


FIGURE 3.7.3

SECTION IV

ENGINEERING

## 4.0 ENGINEERING

### 4.1 TITLE

Interface control documentation (ICD) for support of a future space suit program.

#### OBJECTIVE:

Establish the most efficient and least costly method of controlling the interfaces of future space suits with government and contractor furnished equipment.

#### APPROACH:

The methods of space suit interface control used on the Apollo, Skylab and ASTP programs were examined in addition to new concepts of control.

These concepts were evaluated for efficiency and associated cost effectiveness.

Cost savings data was developed by comparing Apollo, Skylab and ASTP Programs to the recommended new interface technique.

#### GROUND RULES USED FOR STUDY:

1. The space suit ICD program for the period of 1966 through 1973 was used as the study baseline.
2. It was assumed that a new space suit configuration will be used for future suit programs and that the majority of existing interface documentation will not be useable.

#### INTRODUCTION:

During the Apollo, Skylab and ASTP programs, various techniques of interface control were used by both NASA and the associate contractors for the identification and documentation of interfaces. On the Apollo program, the associate contractors performed practically all the interface negotiations among themselves. If a stalemate occurred, NASA would intervene to resolve the contractor differences and additional effort was then continued among contractors.



During this program, NASA acted as a mediator among the contractors and scheduled frequent meetings in order to maintain a punctual resolution of interface problems. This type of close associate contractor interfacing became less effective during the Skylab program as Level "A" ICD's were introduced. During this program, NASA still acted as mediator, but also actively negotiated interfaces with other NASA centers and in many cases without the knowledge or assistance of the contractor who designed and manufactured the equipment. The ASTP program involved the least amount of contractor coordination during the suit program. This occurred since all the suit interfaces already existed on prior programs, therefore, existing ICD's were used.

In this report, the problems of suit interface control experienced during the Apollo, Skylab and ASTP programs were examined. Each problem or group of problems is presented with recommendations for future suit programs which will result in a cost reduction.

The study encompassed investigation of the following areas:

- a. The impact of flight effectivities, part numbers and end item weight changes on the ICD's.
- b. The use of Level "A" ICD's on advanced suit programs.
- c. The duplication and unnecessary information required on many Apollo, Skylab and ASTP ICD's.
- d. The difficulties in the handling of some ICD's due to size.
- e. Cost considerations if new methods of interface control are utilized.

PROBLEM:

Flight effectivities, part numbers, and end item weight changes resulted in numerous Interface Control Document (ICD) and Interface Revision Notice (IRN) changes. In most cases, this information had been previously provided to a contractor in another document.

BACKGROUND:


Flight effectivity notes were required by NASA as a method of configuration control on all Apollo, Skylab and ASTP ICD's. This was done to identify which suit and vehicle or life support system configuration and what mission was being illustrated on the ICD.

Flight vehicle and mission reassignments resulted in numerous Apollo and Skylab suit ICD changes, and nearly all ASTP suit ICD changes. A total of 31 "effectivity" changes were processed during the ASTP program alone. Figures 4-1-1, 4-1-2 and 4-1-3 illustrate examples of typical ILC, Grumman, and Rockwell International ICD effectivity changes.

In all cases, these effectivity changes did not actually effect any real suit interface. In an effort to reduce the costs of processing these changes, Interface Revision Notices (IRN's) were transmitted for signature in groups of more than one. However, much time was still expended in transmitting memorandums and attending meetings to complete the approval of "effectivity" changes.

Similar to flight effectivity changes, part number, and dash number changes appeared on many ICD's and IRN's. In most cases, part number callouts were not required. Identification by part number was necessary for the interface of some hardware since the dimensions were proprietary information.

Since the part numbers were noted, each time the dash number of the vehicle or suit changed, the ICD had to change. In most cases, these changes resulted from component and sub-system changes which did not effect the interface.

 <b>ILC INDUSTRIES, INC.</b> 350 PEAR STREET, DOVER, DELAWARE 19901	TDA02-1020-14-1 ICD NO.		REV.
	TDA02-1020-14 ICD TITLE Electrical Connector Interface Comm. Assembly and CWG or PGA Electrical Harness Assemblies RELEASE DATE		NR
<b>INTERFACE REVISION NOTICE</b> <b>INTERFACE CONTROL DOCUMENT</b>			

DESCRIPTION OF CHANGE:

On Sheet 1, change effectivity

From: CM106/LM4 and sub.

To: CM106/LM4 and subsequent Apollo Flights and ASTP Flights.

Figure 4-1-1

<b>REASON FOR CHANGE:</b> Revise ICD to include Apollo-Soyuz Test Program (ASTP) Effectivity.	DRAWN BY J. D'Andrade
	DATE 4/24/73
	CHECKED BY NO. 74397
	SHEET 1 OF 1
This document specifies technical requirements between all parties affected herein. Nothing contained in this document shall be deemed to alter the terms of any existing contract or purchase order involving I.L.C.	

AUTHORIZED SIGNATURES <i>[Signature]</i> <i>[Signature]</i> CHECKED BY <i>[Signature]</i> <i>[Signature]</i>		REPRESENTING SD-NR ILC PROJ CHECK SPECS	DATE 12/1/73 12/1/73 11/14 11/14 11/14	INTERFACE REVISION NOTICE		CODE IDENT. NO. 03953	RESTRICTED No 13122
SPACE DIVISION NORTH AMERICAN ROCKWELL 12214 LAKEWOOD BOULEVARD - DOWNEY, CALIFORNIA 90241				SYM. A	DOCUMENT NUMBER MHO1-03210-136	REV. P	TITLE ENVELOPE - EMU MAINTENANCE KIT
THIS DOCUMENT SPECIFIES TECHNICAL REQUIREMENTS BETWEEN ALL PARTIES AFFECTED HEREIN. NOTHING CONTAINED IN THIS DOCUMENT SHALL BE DEEMED TO ALTER THE TERMS OF ANY CONTRACT OR PURCHASE ORDER BETWEEN NR AND THE ASSOCIATE CONTRACTOR.				EFFECT ON CM 111 AND 119		RELEASE DATE	COPIES TO: ZIP
DESCRIPTION THIS IPT SUPERSEDES IAN 11691 AND DIFFERS AS FOLLOWS: IN EFFECTIVITY AND SPEC BLOCK. PART NO. F04-100000 WAS F04-100011; IN REASON, ADDED MCR P36510						P. H. ROBE J. MAICCHIE W. PAVEY	P395 P472 P410
IN EFFECTIVITY AND SPECIFICATION BLOCK ADD REQUIREMENTS FOR CM 111 AND 119, AS SHOWN:							
1 F56-006	F04-100019	CM SER NO. 119	SID 64-1345				
2 F34-00	F04-100000	CM SER NO. 111	SID 64-1345				
3 MCR NO.	PART NO.	DESCRIPTION	APPLICABLE SPEC				
REASON ADDED REQUIREMENTS FOR CM 111 AND 119 OF R MCR P36102 1 MCR P36510 2 SUPERSEDED TO CHANGE PART NO.				DR. BY G. LARSEN DEPT./GROUP 696-102 DATE 2-77			

ATTACH 119 COPIES TO DRAWING

AUTHORIZED SIGNATURES	REPRESENTING	DATE	INTERFACE REVISION NOTICE		CODE IDENT NO.	IRN NO:
	GAEC	11/1/70	INTERFACE CONTROL		26512	LID 340-11109 E I
	ILCI	11/1/70	DOCUMENT		ICD NO.	ICRA NO:
			GRUMMAN AIRCRAFT ENGINEERING CORPORATION BETHPAGE, L.I., NEW YORK		ICD NO. LID 340-11109	
			CCA NO.	DATE		
			ICD TITLE	RESTRAINT ASSEMBLY LM RESTRAINT TO P.G.A.		
<p>THIS DOCUMENT SPECIFIES TECHNICAL REQUIREMENTS BETWEEN ALL PARTIES AFFECTED HEREIN. NOTHING CONTAINED IN THIS DOCUMENT SHALL BE DEEMED TO ALTER THE TERMS OF ANY CONTRACT OR PURCHASE ORDER BETWEEN GAEC AND THE ADDRESSEE.</p>						
<p>DESCRIPTION:</p> <p>1. NOTE 1 SHOULD READ "EFF. LM-3 THRU LM-8."</p> <p>2. NOTE 2 SHOULD READ "LM-9 AND SUBSEQUENT."</p> <p>RE/jlc</p>						
REASON: REVISION NOTICE ICD 502					DRAWN BY: M.W. 11/1/70	

Figure 4-1-3

Unlike flight effectivity notes, configuration dash numbers provide absolutely no useful information on the ICD. Since the interface dimensions and other necessary information is provided, the dash number does nothing but confuse an associate contractor unfamiliar with the suit sub-system and components.

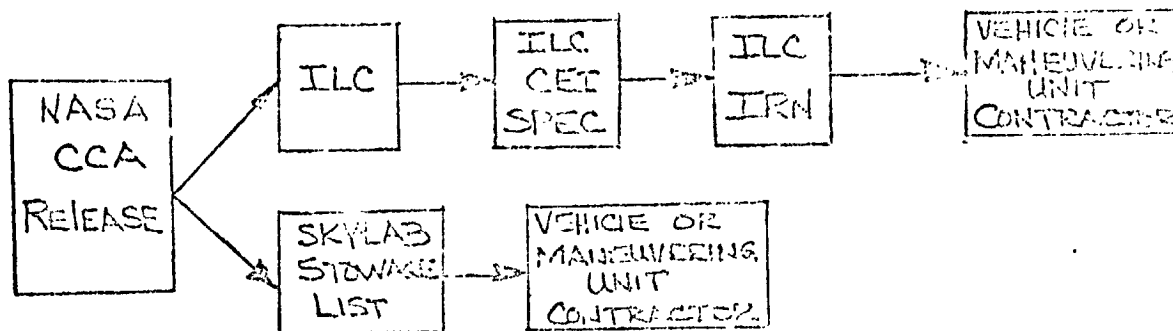
The itemizing of weights on the ICD served to advise the interfacing contractor of the latest suit and suit equipment (LEVA, SEVA, gloves, helmet, etc.) weights for use in the structural design of the vehicle or the operation of a maneuvering unit.

The frequent changing of hardware weights may be an abnormal occurrence for most flight hardware. However, this has not been the case with the pressure suits. Frequent changes have occurred due to:

- a. Changes in mission requirements resulting in substantial design changes necessitated numerous weight changes. An example included the Apollo suit design change from a four hour Lunar EVA to an eight hour mission.
- b. Numerous crew optional items used on the suit were continually being revised or added to the basic suit configuration. Examples of some crew optional items included special comfort pads, comfort gloves, valsalva device, wristlets, quantity of pockets and many others.

On the Skylab program, the suit and suit equipment weights were documented on the Skylab Stowage List. This stowage list was updated as each suit contractor CEI specification weight change was authorized on a contract change authorization. In addition, the suit contractor was required to periodically perform a formal review of the stowage list.

The flow chart illustrates what happened to an approved suit weight change on the Skylab program after the CCA was released.



The stowage list also served as design requirements to the OWS design contractor. As a result, there was no need to document the suit weight changes on the ICD.

This system was not used during the Apollo program or with the Command Module contractor on the Skylab and ASTP programs. As a result, each time the suit contractor received a contract change authorization which changed the suit weight, the ICD required a change.

GUIDELINES FOR FUTURE PROGRAMS:

1. Although the effectivity notations on the ICD's caused numerous change activity, they did serve to advise the reader of the flight mission(s) on which the equipment was intended for use. Therefore, for future programs it is recommended that a separate listing of the individual ICD's and their respective effectivities be prepared and maintained by each contractor. This listing could be part of a monthly status report or other similar documentation which could be used as information to personnel not directly associated with the suit program.
2. Configuration part numbers and dash numbers of the various system, sub-system and component suit hardware, should be omitted from the ICD's when not required.

3. A program stowage list or other similar document, used effectively, is the quickest and easiest method of providing a suit weight change to a vehicle contractor. As long as the stowage list is a contractual requirement for the vehicle contractor, it will eliminate the need to process and transmit an ICD change each time a suit weight change is approved. The suit weights should not be noted on the ICD if the stowage list is used.

PROBLEM:

Interfaces identified on Level "A" ICD's were actively negotiated between NASA centers and in many cases without the knowledge or assistance of the suit contractor.

BACKGROUND:

Level "A" or Intercenter ICD's were utilized on the Apollo and Skylab programs to define the suit interfaces with equipment supplied to a NASA center other than the Johnson Spacecraft Center (JSC). These suit interfaces included:

- a. Suit to Lunar Rover Vehicle (MSFC) - Apollo
- b. Suit and equipment to OWS (MSFC) - Skylab
- c. Suit to T020 Foot Controlled Maneuvering Unit - Langley Research Center - Skylab
- d. Suit to PGA Foot Restraint (MSFC) - Skylab

The ICD's were approved only by NASA JSC and the interfacing NASA center.

When each of these Level "A" ICD's were initiated, suit information was transmitted from NASA JSC to the interfacing NASA center. It was then transmitted from the interfacing NASA center to the contractor preparing the ICD. In one of these interfaces (b), the interface coordination was performed directly between the suit contractor and the OWS vehicle manufacturer at the commencement of the program. This ICD was well coordinated and defined. However, later changes or PIRN's (Preliminary Interface Revision Notices) were initiated by NASA which were not coordinated with the suit contractor until after NASA approval had been made.



In addition, two other Level "A" ICD's (items a and d) were never reviewed by the suit contractor until after receipt of the NASA approved document. In addition, the approval time required for a Level "A" ICD in some cases required several months.

All of this resulted in the suit contractor ICD personnel being less concerned about the accuracy of suit details on the ICD. This resulted because:

- a. The suit contractor interface personnel did not sign the ICD.
- b. Even when the suit contractor attempted to itemize engineering discrepancies on Level "A" ICD's by memorandum, they were in most cases signed by NASA without the recommended corrections.
- c. Many PIRN's were approved without the suit contractor's review since NASA considered them to have no impact on the suit.

In summary, NASA assumed the responsibility for insuring proper interfaces were provided on the Level "A" ICD's as well as the changes (PIRN's). Since the Skylab program used an Apollo configured suit, the interfaces were easily defined and the vehicle and other Skylab hardware was generally designed to fit the suit.

#### GUIDELINES FOR FUTURE PROGRAMS:

Based on past experience, it is believed that the Level "A" ICD's used on the Skylab program for suit interfaces is an undesirable method of control for future programs especially if a newly designed suit is used.

If Level "A" ICD's are to be used in future programs, it is recommended that the interface coordination for the initial or basic ICD and subsequent PIRN's be coordinated directly between the affected contractors, with each indicating agreement by signing an approval sheet. NASA centers can then use this approval sheet to help expedite later NASA approval of these ICD's.

PROBLEM:

During the Apollo, Skylab and ASTP programs, individual interfaces were documented separately in lieu of groups. This resulted in duplication of interfaces, unnecessary information and difficult handling due to the quantity of the ICD's.

BACKGROUND:

The suit ICD's for the Apollo, Skylab and ASTP programs used the philosophy that each individual interface be documented separately.

In addition, mechanical interfaces were traditionally documented on a drawing which ranged from a "C" to roll size while functional ICD's were documented in specification format. This resulted in a total of 98 Apollo, 57 Skylab and 31 ASTP suit related ICD's. Besides requiring massive amounts of paperwork (engineering memorandums, ICD status reports, internal memos for ICD release), these large quantities of ICD's led to the duplication of interfaces and the need to add unnecessary information in order to fill the drawing paper.

Duplication of suit interfaces occurred between ICD's prepared by different associate contractors and the suit contractor.

This occurred when one contractor prepared an ICD illustrating the interface of a specialized piece of his hardware with the suit while a second contractor prepared an identical view of the suit interface with his specialized piece of hardware.

Prior to ICD preparation by an associate contractor, the suit contractor was required to prepare and transmit an illustration of the various suit configurations and changes which occurred during the phases of each program. As a result, the duplication of effort between different contractors was further compounded by the preparation of the initial illustrations which were then copied or traced by the associate contractor responsible for preparation of the ICD.

One cause of this situation was the use of the "pyramid" or "pecking" system used with the Apollo ICD's. When an ICD was required between two or more contractors, this NASA system placed the responsibility of ICD preparation on the associate contractor listed highest on the pyramid. In most cases, this required the contractor below the higher listed contractor to prepare a drawing or sketch which was then copied or traced onto an official ICD by the higher contractor on the pyramid. As a result, the same work was performed twice with each contractor charging NASA for his effort.

Another source of interface duplication was the "Intercenter" or Level "A" NASA interface system used primarily on the Skylab program. Duplication occurred on suit interfaces such as connectors, hard point mounting areas, functional requirements etc., since the interfaces previously documented between the suit and NASA JSC vehicle contractors were again documented on the Level "A" ICD between the NASA MSFC vehicle contractor and suit contractor (NASA JSC). As a result, sketches and views from already existing ICD's were copied onto a Level "A" ICD.

ICD's IDA02-1004-11, IDA04-1031-11, HDA02-715618-11, HDA02-729670-11, MH01-21021-136, MH01-21048-136, and 13M13524 illustrate an example of ICD duplication. These examples illustrate how duplication of the suit connector interface occurred on the Apollo program and was carried over to the Skylab and ASTP programs.

During past suit programs, numerous ICD's were prepared which contained views, dimensions and other information which was not necessary in defining the interface.

Two examples of ICD's which contained numerous detailed views, dimensions and notes of equipment which was not required to describe the interface included:

- a. IDA02-1022-11 "A7LB PGA Pocket Accessories Interface"
- b. HDA02-729629-11 "Mechanical and Functional ICD - Buddy SLSS to A7LB PGA and A6L LCG"

Many other ICD's existed, but these two were readily available at the writing of this report. Inspection of each document reveals the following:

- a. IDA02-1022-11 (two roll sized sheets - each 3 1/2 feet long).

This ICD contains illustrations of each pocket worn on the A7LB-EV and A7LB CMP PCA's. The only dimensions illustrated for any of the pockets are the envelope dimensions called out under each detail. In the case of the scissors, checklist, data list, and utility pocket configurations, each pocket could have been listed by name, part number and inside envelope dimensions without requiring a detailed illustration of the individual pocket. Separate views of the pen, penlight, sunglasses pouch and personal dosimeter could have been illustrated to show the detailed interface dimensions of these items without illustrating the suit pockets. As a result, it would be the responsibility of the suit contractor to insure each of the dimensioned items fit within each particular pocket. Likewise, with the pocket internal envelope dimensions listed on the ICD, it would be the NASA responsibility that the items placed in that pocket would properly fit.

Additionally, the items illustrated on Sheet 2 of this ICD could have all been deleted and discussed in words by adding notes to the drawing. It should be noted that all the additional information contained in this ICD and others like it was not added by the suit contractor to obtain additional profits since all ICD efforts by the suit contractor were accomplished under a "level of effort program". All of the details added to Sheet 2 and all changes itemized in Revision "A" were directed by four separate contract change authorizations.

- b. HDA02-729629-11 - (one roll sized sheet, seven feet long)

This ICD illustrates the interface between the Buddy secondary life support system (BSLSS) and the Apollo PCA. In this ICD, detailed illustrations of the suited crewmen, location of the BSLSS stowage bag on the PLSS and detailed dimensions of the NASA GFE BSLSS hooks was unnecessary. In addition, the views of the suit or PCA multiple water connector and alignment marks was already illustrated on another Apollo ICD, HDA02-713904-13 which was in effect at that time.

These two ICD's represent typical suit related ICD's which contain unnecessary information. Experience has shown that unnecessary information was added to ICD's for several reasons, two of which include:

- a. The use of the ICD by the contractor as a technical document to freeze the dimensions, mounting location and other information in order to expedite the design of the flight hardware before a formal PDR or CDR. The object was to obtain early NASA and contractor approval by rushing through an ICD change. After approval, the ICD was used as leverage for a program cost increase if dimensional or location hardware changes were later required.
- b. It was accepted procedure to always document both sides of an interface on the ICD. This occurred even when no dimensions were contained in the illustration. An exception to this occurred on several North American Rockwell ICD's which contained only the associate contractor's interface dimensions. In this system, only necessary interface information such as the envelope dimensions or functional requirements were noted. The interfacing stowage bag was not illustrated. In these cases, the responsibility for the method of softgoods stowage (foam and duffle bags) was accepted by North American.

Another difficulty experienced with the interface documentation used on past programs was the handling of large roll sized drawings as well as all interface drawings in general. Some of these problems included:

- a. ICD copying delays due to the size of the drawing.
- b. Reproducible copies of all suit related ICD's were kept on file. This required special storage facilities to prevent drawing damage.
- c. Reproducible copies of suit contractor prepared ICD's were transmitted to associate contractors for their files. This required the preparation of special mylar reproducible drawings.
- d. The mailing of drawing originals to associate contractors for signature required the use of special cardboard drawing tubes to protect the drawing during mailing. Mailing by registered mail and special delivery was frequently done to preclude loss.

GUIDELINES FOR FUTURE PROGRAM:

1. It is recommended that all suit interfaces on future programs be documented in a single ICD which is prepared on standard 8 1/2 X 11 inch specification paper. This ICD document would be similar to a suit systems level interface specification and include all suit and other suit related equipment (SEVA, Maintenance Kit, LCG, FCS, etc.). This document would include all the suit contractor interfaces to all associate contractors and NASA, and would only illustrate and describe the suit side of the interface. An approval sheet which would be part of the ICD would be signed by all affected associate contractors and NASA and used as the contractual document defining the suit. Changes to the ICD could be initiated by NASA or a contractor with an IRN similar to the current procedures. A similar systems level ICD was prepared by Boeing Aircraft for the Lunar Roving Vehicle (LRV) during

Apollo program. The LRV was a complex piece of hardware with numerous interfaces. A similar document for the suit interfaces is possible and should work for future programs.

2. As noted in item 1, the ICD should be prepared on 8 1/2 X 11 inch paper to reduce expenses in mailing, reproduction and storage and permit the convenience of carrying the document within a standard briefcase..

COST CONSIDERATIONS:

By implementing the recommended guidelines, it is estimated that the manpower required to support future suit ICD programs can be reduced to a one (1) man "level of effort support" for the duration of the program. This represents a savings of approximately two men that were utilized during the early phases of the Apollo program and one man that was later used at the start of the Skylab program. Additional support would be available from the systems specification or systems test engineers during periods of excessive activity or when interface travel is required to more than one associate contractor or NASA at the same time. The cost savings resulting from the decrease in drafting effort, mailing, reproduction and storage changes could not be estimated but would definitely provide a savings in cost and schedule time.

#### 4.2 TITLE:

Contract End Item (CEI) Specifications optimization.

#### OBJECTIVE:

Determine improvements which can be made to Contract End Item specifications and associated maintenance systems for future space suit programs which will provide the most efficient and least costly method of control.

#### APPROACH:

The CEI Specifications used on the Apollo, Skylab and ASTP suit programs have been studied. These specifications have been examined to determine which requirements or information can be deleted. Those specification items which experienced frequent change activity resulting in excessive maintenance time and expense were identified as prime candidates for possible deletion or change.

An estimate of the manpower saved by implementing the proposed deletions or revisions in future suit specifications is provided.

#### GROUND RULES USED FOR STUDY:

1. The CEI specifications used for the period 1970 through 1973 was used as the study baseline. In some cases, earlier periods of activity were used to support this study.
2. Any new space suit programs will require new contract end item specifications.

#### INTRODUCTION:

During past space suit programs, the Contract End Item (CEI) specifications were prepared in accordance with the NASA "Apollo Configuration Management Manual," NPC 500-1. All requirements for the format, contents and change procedures were imposed on the suit contractor by this manual and little flexibility was permitted.

This study considered several problems experienced during the Apollo, Skylab and ASTP suit programs in the preparation and maintenance of these rigidly controlled specifications, recommendations for improvement during future space suit programs is provided.



PROBLEM:

Frequent changes to suit specification weights and Interface Control Documents (ICD) resulted in numerous CEI specification changes.

BACKGROUND:

Frequent changes to the pressure garment assembly and separable component specification weights have occurred because:

- a. Changes in mission and system design requirements resulting in substantial design changes necessitated numerous weight changes. An example included the Apollo suit design change from a four hour lunar EVA mission to an eight hour EVA mission.
- b. Numerous crew optional items used on the suit were continually being revised or added to the basic suit configuration. Examples of crew optional items included special comfort pads, comfort gloves, valsalva device, wristlets, quantity of pockets and many others.

Each weight change resulting from the addition of a crew optional item or design requirement resulted in a corresponding CEI specification weight change. In some cases, the weight changed by as little as a tenth of a pound.

It should be noted that the control of weights during the Apollo, Skylab and ASTP suit programs did not include a profit incentive plan for the suit contractor. As a result, the suit contractor in most cases did not add safety factors to actual component weights when establishing the suit system specification weight. As a result, the maximum actual weight of the largest suit and the maximum specification weight were generally within one half a pound. This provided approximately a 1% safety factor on the specification weight.

A new method of weight control was instituted through ILC by NASA in 1972 in an effort to reduce this specification change activity. This system was initiated by increasing the specification maximum weight requirement to one half a pound (1%) greater than the agreed upon maximum specification value. Contract changes were made resulting in minor weight increases

to the system (0.1 or less pounds) were recorded and kept on file until the excess one half pound in the specification was exceeded. At this time, authorization was requested and approved to increase the specification value an additional one half pound. This system reduced the number of weight change SCN's to the specifications significantly.

In accordance with NPC 500-1, "Apollo Configuration Management Manual", dated February 1967, Exhibit II, "Interface Requirements" states Paragraph 3.2.1 of the CEI specification shall: ". . . specify, either directly or by reference, requirements imposed on the design of the CEI because of its functional, physical and procedural relationships to other equipment/facilities". As a result of this requirement, all Interface Control Documents (ICD's) pertaining to the end item were tabulated or "referenced" within each CEI specification. Since these were tabulated by noting the approval date and the latest ICD revision letter, each time an ICD document changed (by IRN or revision letter) corresponding change to the CEI Specification (SCN) was necessary. This required either the initiation of an Engineering Change Proposal and the eventual receipt of a Contract Change Authorization since the CEI specification was a Type I Document requiring formal NASA approval or these changes were combined with other formal ECP's during the Skylab Program. This combining of changes reduced the paperwork somewhat during the Program.

GUIDELINES FOR FUTURE PROGRAMS:

1. Two percent increase above the agreed upon maximum specification weight value should be permitted in the system specification. This will decrease drastically the excessive specification change activity caused by individual weight changes.
2. The requirement to conform to Paragraph 3.2.1 "Interface Requirement" in Exhibit II to NPC 500-1 should be deleted since the ICD's are signed by the contractor during approval. If this is not possible, it is recommended that as a minimum, the revision letter and approval dates not be itemized.

PROBLEM:

During the Apollo, Skylab and ASTP suit programs, specifications were prepared for each end item (prime equipment). This resulted in the constant repeating of "boiler plate" type information.

BACKGROUND:

"Boiler plate" information was contained in each CEI specification in accordance with the paragraphs of Exhibit II of NASA Document NPC 500-1. Sections such as natural environments (ground environments) induced environments (flight) materials, parts and processes selection, standard and commercial parts, safety provisions and many other paragraphs constituted "boiler plate" information.

"Boiler plate" information represents approximately 60% of a typical CEI specification where the specifications ranged from 19 to 70 pages in length (excluding tables and figures) depending on the complexity of the end item.

Separate CEI specifications were prepared for each individual end item and each was prepared in accordance with NPC 500-1. Due to this requirement, items such as the LCG water connector adapter assembly required a separate CEI specification. As a result, a total of 12 CEI Specifications were prepared for the Apollo program, seven for Skylab and two for ASTP.

Due to numerous specifications and the use of the same boiler plate information in each, changes effecting one document in some cases required changes to others. An example of this repeatability of one change throughout all the CEI Specifications were the changes to the tabulation of applicability and compliance to MSCM 8080 design standard requirements which required changes in all the specifications several times during the program.

To compound this problem further, each individual contract end item required a separate Engineering Change Proposal (ECP) even if the same change effected several different CEI's. As a result, the MSCM 8080 boiler plate

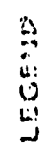
specification changes required a separate ECP be transmitted to NASA for approval for each CEI changed.

Therefore, these so called "no cost" changes actually resulted in extensive "level of effort" manhours to complete some extremely simple changes. Besides requiring additional manpower to type and process the original specifications, manpower was also required to review each separate change, submit engineering change proposals (ECP's) to NASA, process SCN's and support the Contractor's Configuration Control Board (CCB).

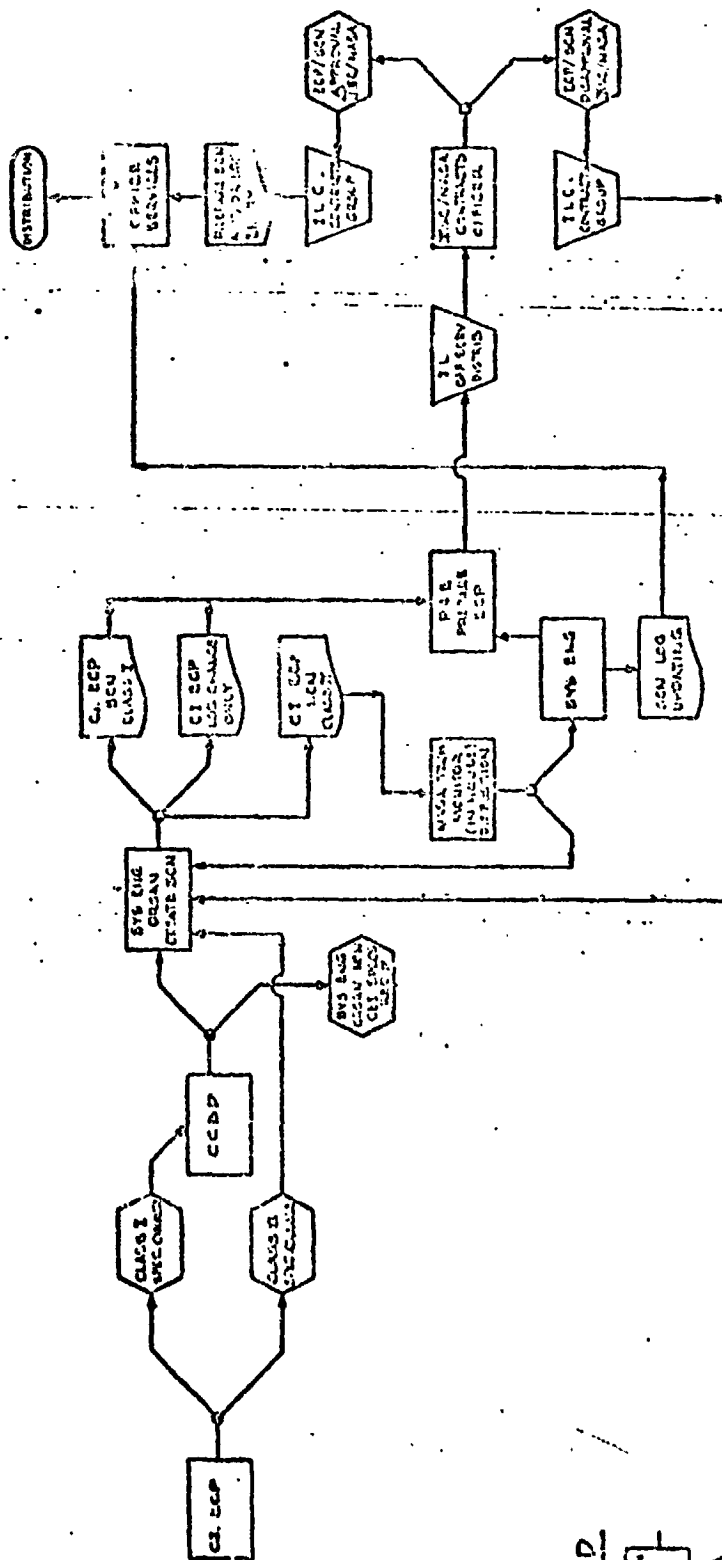
The flow diagrams in Figures 4-2-1 and 4-2-2 illustrate the various activities within ILC that were involved in the approval route for the CEI Specifications. It can be seen that even a small reduction in the number of specification changes or in the number of specifications produced during the program can have a significant effect on the manhours of support manpower required during a program.

#### GUIDELINES FOR FUTURE PROGRAMS:

In order to reduce the manpower required to support the initial preparation and maintenance of CEI specifications, it is recommended that one CEI specification be prepared to describe all the space suit end item requirements. This would reduce the manpower required to support both the initial preparation and the later maintenance of the documentation. It should be noted that this recommendation is in violation of NASA Document NPC 500-1. If the implementation of this change on future space suit programs is desired, the applicable requirements of NASA Document NPC 500-1 should not be imposed on future suit contractors.



HOLLYWOOD, CALIF. (UPI) - A  
 1955 Buick Wildcat convertible  
 was stolen from a parking lot  
 near the Beverly Hills Hotel  
 last night, police said.  
 The car was stolen from a  
 parking lot near the Beverly  
 Hills Hotel, police said.  
 The car was stolen from a  
 parking lot near the Beverly  
 Hills Hotel, police said.  
 The car was stolen from a  
 parking lot near the Beverly  
 Hills Hotel, police said.



**DN337**

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[illegible]

FIGURE 4-2-2.  
FLOW DIAGRAM FOR CHANGING OF A C&T SPECIFICATION  
FOR A CONTRACTOR INITIATED ECP

PROBLEM:

The configuration management program required a CEI specification approval system which created delays in incorporating equipment design changes.

BACKGROUND:

During the Apollo program and part of the Skylab program, specification change notices (SCN) were prepared to document a CEI specification change in accordance with NPC 500-1. Per NPC 500-1, all SCN's require submittal to the procuring agency prior to their distribution at the contractor's depot. (Ref. Para. 6.1, Exhibit VII of NPC 500-1.) This approval system resulted in many changes (SCN) requiring an approval time of up to six months. This was due to the extended time for the preparation and submittal of the necessary engineering change proposal (ECP) by ILC and the complexity of the NASA approval system.

An additional problem also resulted from the requirements of the SCN approval system. This occurred when several different SCN's were submitted to NASA and each affected the same paragraph of the same specification. Examples of this occurred in changes made to the interface control document listing, weights, field optional item list, standards of manufacturing (process specs table) and others. Each SCN was documented on a separate engineering change proposal (ECP) since different design changes were issued on separate contract change authorizations (CCA's).

In accordance with Paragraph 6.1.1.5 of Exhibit VII to NPC 500-1, each SCN was required to state the original specification paragraph being changed ("changed from") and the recommended new replacement paragraph ("changed to"). As a result, when several SCN's were prepared against the same specification paragraph due to different CCA's, each SCN referred to the same latest approved specification paragraph. Therefore, once one ECP and SCN was approved by NASA, the remaining ECP's and SCN's would be rejected since these SCN's no longer stated the latest "changed from" paragraph of the specification. This occurred because

approval of the first SCN revised the wording of the affected paragraph.

In an effort to resolve this paperwork problem, ILC revised the Skylab/Apollo configuration management plan, 881270043D. Exhibit 1202, Paragraph V-A and F of the plan, contains the following SCN approval system agreed upon by ILC Dover and NASA/JSC:

"For expediency in implementation, the NASA Resident Engineer, based on the concurrence with the NASA/JSC Technical Monitor (or his designee), will approve the SCN, by signature, prior to ECP submittal/approval. In these instances, the SCN will be officially released and implemented. Subsequent changes, related to ECP approval will be implemented by an additional SCN which will be made part of the original ECP package."

"SCN's which do not reflect signatory approval at time of ECP submittal will not be implemented until the ECP is approved. When this occurs, CMO will be responsible for obtaining NASA Resident Engineer approval prior to release and implementation of the SCN."

When the SCN was approved in accordance with this system, it permitted any subsequent SCN's changing the same paragraph to reflect the new "changed from" paragraph. This occurred since the normal approval time was approximately one to five days. Once this approval was received, the approved SCN was then submitted to the ECP eliminating the problems experienced in the past. It should be noted that this system did contain one drawback, the risk of ECP disapproval by NASA/JSC. Recognizing this remote possibility, a procedure was incorporated in ILC Document 881270043D, Exhibit 1202F stating the following:

"In the event an SCN is subsequently disapproved/modified, after NASA Resident Engineer approval and official release, the applicable CCBD will be revised to identify action required."

"SCN's will never be revised. Subsequent changes incorporating modifications or retracting a previous SCN



(in total) will require a new SCN. In cases of total retracting, the previously superseded pages will be re-activated with the latest SCN number added and the Release date changed. The change log will be updated to reflect the latest SCN and other required data."

In actuality, less than 1% of the SCN approval and preparation time was used to prepare new SCN's due to customer disapproval of the ECP.

GUIDELINES FOR FUTURE PROGRAMS:

It is recommended that a specification change notice (SCN) system similar to that discussed in ILC Document 881270043D be utilized on future space suit programs. This procedure should be used in lieu of the recommended NASA procedure discussed in NPC 500-1. Utilization of this new procedure will result in a significant cost savings in manpower for the preparation, review and copying time involved in rewriting SCN's. In addition, a definite schedule savings will also result since the submittal and approval time for engineering change proposals could extend to six months.

CEI SPECIFICATION COST CONSIDERATIONS:

By implementing the guidelines discussed and assuming a similar rate of change activity as in past programs, it is estimated that the manpower required to support future suit specification maintenance activities can be performed by one (1) man for the duration of a program. This represents a savings of one man over the level required to perform this function during most of the Apollo and Skylab programs.

#### 4.3 TITLE:

Field Operating Procedures

#### OBJECTIVE:

To review the systems and philosophy used during Contract NAS 9-6100 for preparation and maintenance of Field Operating Procedures. To identify guidelines that might be employed on future space suit programs that would effectively reduce costs for preparing and maintaining Field Operating Procedures.

#### APPROACH:

Field Operating Procedures were analyzed in terms of contract requirements, format, methods of change, ease of use and effectiveness. Level of detail of these documents was compared to the depot Table of Operations (TO's) to determine if cross-utilization could be implemented. Emphasis was placed on identifying areas within the Operational Procedures that could be modified to effect cost savings. Future program guidelines are recommended in areas of potential cost savings. Potential savings are presented by comparison of level of effort required on NAS 9-6100 and projected level of effort for future programs employing the recommended guidelines.

#### INTRODUCTION:

Field operational documents as referred to in this study consisted of the following documents:

Maintenance Manual (No. 8819700712)

Illustrated Parts Breakdown (No. 8819700713)

At the initiation of this study, the Chamber Pre-installation Acceptance Test Procedure and the Flight Pre-installation Test Procedure were to be included in the analysis of field operational procedures. However, a preliminary survey identified very few cost related problems with them. These documents were revised prior to the Skylab program to incorporate a test sequence that had evolved through several years of successful use. Personnel using these documents expressed overall satisfaction with the format and adequacy. On the basis of the results of this preliminary survey, these two documents were deleted

from the study.

The Maintenance Manual (MM) is a two volume (1,013 pages) technical publication containing descriptions of space suit equipment and systems with instructions for effective use including operational instructions, maintenance and overhaul instructions, assembly parts lists with supporting illustrations and modification instructions.

The illustrated Parts Breakdown (IPB) is a single volume, 309 pages, parts list which supplements the Maintenance Manual and is used primarily for spare parts definition.

The MM and IPB resulting from Contract NAS 9-6100 evolved from four years of continued support activity which included many reviews and modifications to the format and the required level of detail. Having a complete, current and understandable document is necessary for performance of quality CEI maintenance in the field. A survey of users indicated general satisfaction with the document in meeting its intended objective. These technical publications were of a high standard and as such were expensive to prepare and maintain in relation to other space suit operational documents. These documents required an average of two engineers, a technician and part time use of an illustrator to maintain throughout most of the program. Labor costs associated with this activity were charged on a level-of-effort basis, that is, the required personnel were maintained throughout the program to support any tasks associated with maintenance of technical publications and their time was not charged to contract changes.

PROBLEM:

The Maintenance Manual and IPB were expensive to prepare and maintain throughout the space suit program.

BACKGROUND:

The Maintenance Manual was required to be an all encompassing document and contain a very high level of technical detail. The text is concise, comprehensive, and

so worded as to be understandable to a high school or service school graduate with knowledge of the applicable general theory and technical terms used in the space suit field and with some practical experience. Illustrations consisting of art work such as graphs, photographs, charts, diagrams, and drawings are used to support the text. The illustrations used in the manual required more detail than normally found on drawings. While drawings are usually of a full front view, many of the illustrations required a three quarter profile which are not readily transferrable from drawings. At the completion of the contract, the MM and IPB contained a total of 185 illustrations. An average illustration required 30 hours of time to prepare.

Technical descriptions and illustrated details concerning all current Class I and Class II configurations had to be maintained. All space suit models that were in current use had to be included. At one time during the program, this included the A7LB Apollo, A7LB Skylab, Command Module Pilot (CMP) and the Apollo-Soyuz Test Project (ASTP) space suits. Since the Maintenance Manual is the only technical publication in use by field personnel, it serves as a "catch all" for all non-testing technical directions. Field Operations Bulletins, System Safety Notices and Standard Repair Procedures had to be incorporated into the document as part of routine maintenance.

References to other existing operational procedures were not permitted. Notes and warnings had to be repeated throughout the document instead of including them in the general section and referring to them when applicable. If design changes affected one section of an illustration and did not obsolete the current configuration, it required the complete redrawing of the illustration, rather than showing both approved configurations on the same illustration. Cleaning instructions were contained throughout the manual. Although complete and current procedures existed in other Class I documentation, reference to these procedures were not permitted.

Separate and different operating instructions were used by the depot and field even though they performed many similar activities. Depot TO's are detailed step-by-step manufacturing instructions describing fabrication of an end item. They contain all the sequences, specifications, inspection points and material identifications that are required to fabricate a suit. The instructions are tailored to the use of all new materials and all assembly work starts from zero flow. Disassembly instructions are not contained in TO's. Production operators normally do not have to contend with the difficulty associated with working on a total space suit assembly. TO's were not prepared in Maintenance Manual format because the sequence of work was not compatible with maintenance activities. When CEI modifications were performed at the depot, rework instructions, prepared in the TO format, were used in lieu of the Maintenance Manual. Additionally, the pressures of the manufacturing schedules never permitted sufficient time to insure that TO's were written in a format useable for both depot and field activities. Less time was required to address the rework instructions to the conditions that prevailed for the particular job in-flow. Although the Maintenance Manual was useable at the depot in some instances, complete utilization was never considered because of the following reasons:

- A. Depot rework nearly always involved work on structural members of the space suit. The Maintenance Manual did not address itself to the rework of structural seams since it was not an authorized field maintenance activity.
- B. Since most of the instructions needed to perform rework were already contained in existing TO's, it was more expeditious and economical to change a TO to fit the particular rework problem than attempt to update existing Maintenance Manual instructions.

CEI design changes were excessive during certain periods of the space suit program. This caused a high turnover on Maintenance Manual changes. During 1971 and

1972, a total of 80 changes were processed to the Maintenance Manual and IPB. These changes required modification of 2,378 text pages and 173 illustrations. Based on established standards, processing of these changes required over 12,000 man hours.

The level-of-effort method of maintaining the Maintenance Manual and IPB created a situation whereby change direction to the Maintenance Manual was directed with little regard for associated costs. The Customer insisted on maintaining the initially established standards, even though the experience level of field technicians had increased. This required long-term extension of required support personnel.

GUIDELINES FOR FUTURE PROGRAMS:

1. Future CEI designs should place more emphasis on field maintainability. Future programs should authorize all levels of modification, maintenance and repair by field personnel and incorporate appropriate instructions in the Maintenance Manual. This guideline will probably increase the initial preparation cost of maintenance publications, but will result in considerably less program costs when compared to the cost of returning CEI's to the depot for modification. Major CEI overhaul should continue to be performed at the depot in order to keep logistics and tooling costs to a minimum.
2. Table of Operations (TO's) should be utilized as the assembly instructions in the Maintenance Manual whenever practical. Initial preparation of TO's should consider subsequent field use as a major objective. A section describing disassembly procedures could be provided to supplement TO assembly instructions.
3. Use of references should be permitted within the Maintenance Manual when practical. Documentation which is developed and maintained specifically to perform other related activities should be

referenced in lieu of incorporating the actual verbage in the Maintenance Manual. Notes, cautions, etc. should be contained in a general section of the document, and only repeated in the body when absolutely necessary. When simple design differences exist between assemblies or sub-assemblies, allow the use of one illustration to depict both authorized configurations.

4. The requirement to perform a Customer review in 20 working days should be enforced and when not complied with, allow the contractor to release the change without further delay. Delays of change release create a pyramid effect and causes expensive backlogs and delays on maintaining a current document.
5. Maintenance Manual change activity should be handled on a CCA instead of a level-of-effort basis. This will insure proper forethought before requesting changes that are not absolutely necessary. This would eliminate a high percentage of changes caused by personal desires when techniques or manner of presentation is the only thing in question.

COSTING:

Preparation and maintenance of Technical Publications was performed on a level-of-effort basis during Contract NAS 9 6100. As many as seven people were utilized full-time on this effort during certain phases of the program. Initial preparation costs were high since very little technical information was available for use as groundwork. A large part of the initial art work was performed by outside contracts since the Company capabilities in this area were limited. As the program matured, additional capability was developed in-house and the writers became more familiar with the suit design and associated manufacturing techniques. When the A7LB model space suit was introduced, the publications

group had stabilized to a level of two engineers, one technical writer and one illustrator. This level was maintained until early 1972 when the illustrator was phased out. Cost data compiled from July 1971 through the end of the contract (September 1973) reveals that a total of 85 man months was expended on technical publication support. This equates to slightly over 3.1 men per month. During this period, three major changes were processed which incorporated the CMP, Skylab, and ASTP configured suits. The change for the ASTP required approximately 165 new ext pages and modification to 323 other pages. Thirty-seven new illustrations were required. On the basis of established standards, preparation of this change required approximately 3,400 man hours or over 90% of the total time spent on technical publications during the ASTP period. It is apparent that the bulk of support was used in incorporating text and illustrations for new models. On a program that is relatively stable in terms of design changes, most of the support cost would be eliminated. Incorporation of cost savings guidelines recommended herein would result in further cost reductions. It is probable that one full-time person with part-time support of an illustrator could have maintained the required technical publications after establishment of the qualification baseline. This would have resulted in a savings of 17 to 20 man months per year during the operational phases of the program.



#### 4.4 TITLE:

Engineering Organization and Manpower Summary

#### OBJECTIVE:

Evaluate the engineering organization that existed during the A7LB and ASTP space suit programs. Recommend changes that would result in reduced overall costs while still providing an efficient and effective engineering operation.

#### APPROACH:

The ILC functional engineering organization in effect during the A7LB and ASTP space suit programs is used as a comparative baseline. Areas that contributed to excessive engineering costs are identified. These areas are reviewed to identify reasons for excessive costs and recommendations are made on means of reducing associated costs. These are presented in the form of future program guidelines relative to each problem area. Cost savings are reflected in a proposed organization chart that is compared to a factored A7LB organization chart.

#### GROUND RULES USED FOR STUDY:

1. The engineering organization for the period 1970 through 1973 was used as the study baseline. In some cases, activities of earlier periods were used to support trade-offs. Emphasis was placed on reducing the level of required engineers. The effects on supporting personnel (draftsmen, technicians, etc.) was assumed to be proportional (See Figure 4.4.1).
2. The proposed engineering organization was manloaded to support the program schedule presented in section 3.4 of this report (See Figure 4.4.2).

#### INTRODUCTION:

In an aerospace program, engineering organizational structure and responsibilities are principally the responsibility of the contractor. Very few specific operational requirements concerning engineering are imposed on the Contractor. Exceptions

are requirements to provide drawings and design requirements imposed during the development and qualification phases of the program. In most cases, the Project Manager has sufficient flexibility to allow him to organize in the manner he feels will get the job done best. Direction from the Customer is nearly always in the form of recommendations.

In this report, several problems that were considered to be causes of excess costs have been identified. The nature and causes of the identified problems are varied. Some were a result of contract direction and some because the dynamics of the program didn't allow time to develop more efficient systems. In each case, guidelines are given as a means of eliminating or reducing these costs. In most cases, the savings are identified in terms of reduced man hours. However, the amount of savings realized on a future program would be primarily a function of how the Project Manager elects to organize his engineering department. If he elects to use engineering primarily as problem solvers once development is complete, costs will be lower. However, if he feels the need for a large engineering force after development is complete, costs will be higher. On any new program, a manpower trade-off study based on management objectives must be performed after the development phase to determine the level of engineering required. In this report, an engineering organization is proposed that will be based on implementation of all or most of the included guidelines. The manpower level of this organization is then compared to the level of the engineering organization that existed at ILC during the period 1970 to 1973. The man loading of the 1970-1973 organization was based on an average 1/5 production rate. Manloading differences between the proposed organization and the 1/20th factored organization are a measure of the savings associated with the recommendations of this report. See Figure 4.4.3.

#### BACKGROUND OF A7LB ENGINEERING ORGANIZATION:

The Apollo, Skylab and ASTP Engineering Organization reported directly to the Program Manager. The engineering

organization operated as a "line" function throughout the total program and was involved in nearly every aspect of the program. It was managed by a chief engineer who reported directly to the Program Manager. He had total responsibility for the Apollo engineering group and functional responsibility for all other engineering personnel supporting the Apollo group.

The organization consisted of personnel assigned directly to the Apollo group supplemented by engineers or support personnel from other company non-Apollo groups. The organization primarily consisted of four engineering disciplines; design, project, systems and documentation.

Project engineering responsibility was sub-divided into major CEI's or groups of CEI's that were associated in some respect. As an example, one project engineer was assigned responsibility for the Integrated Thermal Meteoroid Garment, Extravehicular Visor Assembly and EV gloves. Each of these CEI's are associated through emphasis on its thermal requirements. Additional junior project engineers were then assigned to the lead engineers. Since every Contract End Item (CEI) was assigned as the responsibility of a project engineer, all major decisions effecting CEI's were made by the project engineer or by a group in which the project engineer was a prime contributor. Some typical responsibilities of a project engineer were: CEI coordination, flight support, engineering change activity, requirements definition and failure analysis support.

Design engineers were assigned to project engineers in accordance with their respective expertise. Historically, these were people that had gained their space suit knowledge through long experience and were involved with the CEI from the concept stage through production. Typical responsibilities of a design engineer were: CEI design and development, production and retrofit problem support, manufacturing instructions, tooling design, fitcheck support, engineering drawings, engineering change activity, and testing.

The system engineering group was primarily responsible for all activities that dealt with the total spacesuit system. It included all manned testing, final CEI acceptance testing, fitchecks, qualification testing, interface coordination and system level documentation.

The documentation group was responsible for the majority of all non-system level documentation generated in the engineering group. This included engineering change orders, process and procurement specifications, drafting, field operational documents and modification instructions.

A small material engineering group reported directly to the chief engineer because support from this group was usually required by all sub-groups within the organization. Some typical responsibilities of this group included: materials selection, evaluation and testing, generation of material specifications, and production trouble-shooting.

The remaining organizations consisted of an engineering planner who performed scheduling, costing and activity coordination, and a test engineer whose prime responsibility was coordinating and directing space suit test activities in the test labs.

PROBLEM:

Throughout the ILC space suit program, several support functions which were primarily performing production tasks were assigned to the engineering organization. Costs associated with these non-engineering tasks were charged to the engineering department.

BACKGROUND:

The functions included glove modelmaking, pattern making and test technicians.

The glove model maker's major responsibility relative to the suit program was development of molds used for the manufacture of custom gloves. This task consisted of making a master mold from the astronaut hand cast and using it to make the custom manufacturing mold. Time standards were developed early in the program and were fairly consistent regardless of the size of the hand. With the exception of a few design improvements, the techniques used

by the glove modelmakers were relatively unchanged throughout the program. Following development of the molding techniques, which occurred very early in the program, this was primarily a manufacturing support function and should have been assigned organizationally to that department.

The pattern making function was very similar to the glove modelmaking function in terms of engineering versus manufacturing support. During the development phase of a program, the pattern maker develops the patterns necessary for the intended design. From that point on, his major responsibility is developing custom and sized patterns to meet production requirements for assigned astronauts. Again this was primarily a manufacturing support function and should have been assigned organizationally to that department.

Test technicians perform a large variety of functions in support of a suit program. An attempt to make a realistic estimate of technician's work load associated with engineering and that associated with manufacturing would be impractical, since it varied according to the dynamics of the program. However, several functions performed by the technician group could readily be identified as production-associated. These tasks included daily testing of adhesive samples, weekly testing of material properties, fitcheck support and equipment calibration and repair. These were routines that were relatively standard in terms of time and varied primarily as a function of the production rate. Because of the structure of the organization, these functions were the responsibility of engineering and in many cases costs associated with these functions were charged to engineering. This was especially true when idle time occurred or when the nature of the particular job was difficult to identify. A prime example occurred during the trouble-shooting of a manufacturing problem when detailed direction of the technician was usually provided by an engineer. This time was normally charged to engineering rather than manufacturing.

With the possible exception of improved communication and coordination, reassignment of functions identified

herein would probably not result in a new program saving. However, from the standpoint of cost management, proper assignment would result in a more realistic distribution of program costs, and in this situation would have resulted in a smaller share of total cost being identified as "engineering costs".

GUIDELINES FOR FUTURE PROGRAMS:

Personnel supporting the manufacturing process should be assigned organizationally to the manufacturing department or the manufacturing department should be responsible for the financial management of tasks supporting their effort.

PROBLEM:

Changing mission requirements caused continuous qualification activity which in turn dictated a high level of continuous engineering support.

BACKGROUND:

In a period extending from February 1968 through February 1972, active cycle qualification testing was in progress for 29 months or approximately 70% of the 49 month period (see Table 1). Approximately 72% of the test time was utilized in testing to meet new or redefined mission requirements. The remaining time was spent in qualifying for a combination of equipment failures and design changes such as adding arm bearings and large wrist disconnects. Fifteen months were expended on the A7LB suit while the remaining time was spent on the A7L suit. The elapsed times noted on Table 4.4.6 reflects active test time and does not include additional time spent in preparation of test plans, procedures and final reports. For all practical purposes, it can be stated that qualification test activity was in progress throughout the total period.

Since this task deals only with the engineering organization, no attempt will be made herein to develop a total cost of the qualification activity performed during the A7L/A7LB suit program. The objective of this section is to

identify engineering costs associated with qualification testing and recommend methods of reducing these engineering costs. Through a review of program engineering charges, it has been estimated that four man months per month of engineering support was required to support each month of qualification testing regardless of what phase the program was in. This support consisted of a combination of softgoods, hardgoods, pattern designers and systems test engineers. This support does not include the design, development and DVT time expended on the CEI prior to the start of testing, but does include time spent in qual failure redesigns and preparation of qualification documentation such as plans, procedures, TRR's and reports. On this basis, it is estimated that a minimum of 196 man months of engineering time was expended in direct support of qualification test activity in a four year period. If complete and correct A7L and A7LB mission requirements had been available prior to the start of testing, it can be assumed that only the Mission C and Mission J test programs would have been necessary. These two programs required seven and nine months of elapsed time respectively. On the basis of four man months/month of engineering support and allowing a 40% increase to cover test preparation, reports and contingencies; total time expended for these two programs would have been

$$4 [ (7 + 9) + 0.4 (7 + 9) ] = 89.6 \text{ man months of effort.}$$

The attainable savings would have been 196 - 90 or 106 man months of engineering.

The attached man loading chart (Table 4-4-4), reflecting engineering requirements for a future program, show performance of a qualification program in a seven month period. This proposed program takes advantage of qualification by subassemblies to minimize total qualification flow time. Again, allowing a 40% increase in time for test preparation, final report and contingencies, total time would be

$$4 [ 7 \times 0.4 (7) ] = 39.2 \text{ man months of effort.}$$

It is obvious that considerable savings can be attained by minimizing qualification test time. In addition to savings of direct qualification test support time, similar engineering savings will be realized by the reduction of personnel needed to perform delta DVT and component bench tests.

GUIDELINES FOR FUTURE PROGRAMS:

1. Cycle requirements must be thoroughly defined for all possible missions that might utilize the CEI being qualified. If this is not possible, the CEI should be subjected to cycle endurance testing to establish its useful life.
2. If failures occur during the qual testing, a trade-off should be performed to determine if the item should be redesigned and retested or classified as a limited life item to the extent that cycle testing had been completed.
3. Subassembly qualification as reflected in section 3.4 should be utilized to preclude test delays if a failure should occur. On past programs, a failure to any part of the CEI required complete termination of testing until the failure was analyzed and corrective action defined and implemented.
4. Overtesting should be prevented. Several examples that occurred during the A7L/A7LB programs were: initial safety factors were set too high, no allowance was made for "1 g" versus 1/6g effects on the CEI and astronaut mobility techniques such as "young's Rocks" caused undue stresses on the CEI and resulted in a test failure and expensive redesign. In the latter case, redesign could have been precluded by definition of allowable mobility techniques.

PROBLEM:

Astronaut fitchecks were performed at the depot as part of the pre-delivery acceptance test which required a significant amount of engineering support.



#### BACKGROUND:

Because of the integrated design of the A7L and A7LB space suits, it was necessary that fitchecks be performed at the depot. In order to obtain optimum fit of the CEI, it was imperative that cable lengths were correct. In addition to affecting suit fit, improper cable lengths could cause premature failures and restrict mobility. Since the cables were beneath the Integrated Thermal Meteoroid Cover (ITMG) and were attached with permanent fittings, it was necessary that correct cable lengths be established and permanently installed prior to integration of the ITMG and final acceptance testing.

Each fitcheck required an average of 52 manhours of support by softgoods, hardgoods, systems, project and manufacturing engineers. This support consisted of pre-fitchecks, preparation of supporting hardware and facilities, coordination of supporting personnel and the actual fitcheck. This 52 hours did not include engineering time required in correcting fitcheck discrepancies. On this basis, the 200 PGA's procured on NAS 9-6100 required roughly 10,400 manhours of engineering fitcheck support. It is estimated that elimination of fitchecks would have resulted in the elimination of one full-time engineer during the life of the contract. Other savings not reflected in this report would have been realized in the areas of technicians, quality inspectors and program personnel; cost of facilities and equipment to support fitchecks; and savings associated with more efficient utilization of astronauts' training time.

#### GUIDELINES FOR FUTURE PROGRAMS:

Impose a design requirement that initial fitchecks of future space suits be accomplished at the user facility, i.e., do not make fitcheck a requirement of PDA. To accomplish this, a modularized suit with simplified sizing adjustments should be considered. Use of permanent sizing cables, which are one of the prime reasons for depot fitchecks, should be reduced or completely eliminated. With modularization,

slave sub-assemblies could be used for pre-manufacturing size selection. Ideally, the only sub-assemblies that could not be preselected on the basis of slave units would be the gloves. The few times that a suit might require return to the depot for rework as a result of a fitcheck problem would be far less expensive than having the astronauts commute to the depot.

PROBLEM:

Limited resources of other engineering groups within the company required the space suit group to maintain a minimum of critical engineering skills.

BACKGROUND:

In terms of employees, ILC is considered a small company. Historically, its product line has been limited to speciality items. Examples of company products other than space suits were helmets, face shields, inflatable structures and other miscellaneous personnel protective gear. During the space suit program, an average of 80% of ILC's business was with NASA. The pool of engineering resources outside the suit program was limited and the company product line was such that a large non-suit engineering staff was not required and could not be supported. Therefore, most of the engineers employed by the Company were hired expressly for working on the space suit program.

A space suit program requires an extensive amount of unique engineering expertise. The high quality and reliability requirements dictate the need for design specialists in areas such as softgoods, materials, hardware, human factors, manned testing and patterning. Many of the required skills are not taught as part of a classical engineering curriculum, but are learned through experience.

In large companies, necessary design engineering talent would be drawn from the company engineering department when needed and returned to the engineering department when his services were no longer required. In the event of problems requiring his expertise, he could be recalled for short-term support. Small companies such as ILC, not having the surplus

resources available, must hire personnel to meet the requirements of the individual programs. Under these conditions, the engineer must be supported almost entirely by the program for which they were hired. When contractual commitments require that the contractor be prepared to support resolution of any design problems occurring throughout the program, it is imperative that the company retain as many of the "experts" as practical. This can be costly but is the trade-off that must be made in order to insure that the talent is available when required. The dynamics of a space suit program, with its costly penalties for schedule delays, usually leave no other alternatives for a small contractor.

OPTIONS FOR FUTURE PROGRAMS:

1. NASA should supply services associated with certain engineering specialist skills. An example of this would be in stress analysis whereby NASA could supply complete support in the form of analysis, testing and specifications. This system would probably result in increased flow time for development and change activity but in a program with limited change activity, it could result in a net savings.
2. NASA could perform all failure analysis with contractor approval. Excluding engineering activity caused by mission requirement changes, failure analysis is probably the most expensive design engineering activity that occurs after qualification. Qualified personnel must be retained in the organization to handle all levels of failure. The facilities and resources that exist at NASA might allow this function to be performed by them at considerably less expense.

Another option available would be for NASA to retain responsibility of product redesign and use the Contractor primarily for retrofits and mod kit fabrication once qualification is completed.

PROBLEM:

Manufacturing engineers were not given enough responsibility. This resulted in design engineers spending a significant amount of time supporting production floor problems.

BACKGROUND:

In the early days of the space suit program, very few personnel were familiar with the design and fabrication of the space suit.

These were the design engineers who developed the suit and were engrossed in design modifications as well as preparation of all documentation required for production. Tight program schedules resulted in the design engineers making key technical decisions to solve manufacturing problems. This occurred because the manufacturing engineers were delegated the role of production supervisors until they gained enough experience to make technical decisions. Eventually, it became necessary to assign a design engineer full-time to the production area.

Through the last quarter of the program, a committee consisting of a design, manufacturing and quality engineer was assigned to the production area to support manufacturing activities. This system, although effective, was inefficient and costly. However, as the program matured, the manufacturing engineers acquired the experience and were delegated additional responsibilities.

The design engineer was then required only on an "as-needed" basis. This transition was lengthy, inefficient and expensive and was caused by not allowing adequate time during the development phase for training of personnel.

GUIDELINES FOR FUTURE PROGRAMS:

1. Manufacturing engineers should get involved during the CEI development process to the extent of writing detailed manufacturing instructions and recommending techniques that will expedite flow or reduce costs when the CEI goes into production.

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2. Discrepant conditions and the level of criticality must be clearly defined to preclude lost time caused by generating unnecessary discrepancy reports.
3. Manufacturing tooling requirement should be the responsibility of manufacturing engineers. Participation of manufacturing engineers during the development process will reduce the number of "one-time only" tools made for the purpose of checking out design concepts.
4. Design engineers should serve only as a support function to manufacturing once the production phase has started. They should only be used on an as-needed-basis and only when the problems are one of a design nature.
5. Manufacturing engineers should be given increased responsibility in the disposition of discrepancies.

PROBLEM:

Activities were performed by the engineering group that were redundant and could have been performed as effectively by other program groups.

BACKGROUND:

Engineering Liaison was a small group within the engineering organization that was responsible for engineering change orders and operational specifications. As their title implies, they performed liaison functions between engineering, drafting, CMO and the program office. The group was originally formed to process the engineering documentation required for engineering changes. During the periods of extensive design change activity, it was determined that project and design engineers were devoting an extensive amount of their time to processing change documentation. The majority of the workload was created by the contractual requirements of MIL-D-1000 which necessitated total documentation of assemblies, sub-assemblies and component parts of the suit. A change to a simple piece part could affect as many as seven levels of drawings in addition to process, procurement

and test specifications. As the workload became excessive, backlogs occurred and changes to second level documentation were being overlooked. Liaison engineers were tasked to identify all documents effected by a change and to insure that all changes were completely and correctly documented. The necessity of this group was justified under the circumstances that existed during the Apollo program. However, if drawing requirements are reduced (see Section 3.1) on future programs, the need for an engineering liaison group would be reduced.

- The responsibilities performed by this group could then be divided between the engineering organization and the Configuration Management Organization (CMO). Preparation of technical documents such as process and test specifications would remain the responsibility of engineering while the processing and coordinating of engineering change documentation would be performed by the CMO group. This transfer of responsibility is considered feasible since much of the check-and-balance and coordinating activity performed by the Liaison Engineering Group was redundant to activities performed by the CMO group.

A flow process chart is presented (Figure 4.4.5) as an example of one of the cost savings that could be realized by transferring ECO responsibility from the engineering liaison group to CMO. By merely transferring the functional responsibility, the elimination of coordination and transportation time amounts to a savings of 52 minutes per ECO. Although 52 minutes seems insignificant, when multiplied by the average 700 ECO's that were processed per year, this amounts to a savings of over 600 man hours per year. This same savings would be attainable on other types of change documentation. Additional savings not reflected on the flow chart result by the use of less expensive personnel to perform the same function. Other areas of duplication that occurred between CMO and Engineering Liaison were: control of changes to manufacturing instructions; control of specification change notices, participation on the change review board, and maintenance and control of component lists.

Total responsibility for these functions can easily be transferred to a CMO group without hindering or affecting the effectiveness of the engineering group.

The size of the engineering liaison group varied during the A7LB program. The group reached a level of five people during the Apollo and Skylab development phases. During these periods, new documentation was being generated on the new model suits while concurrent changes were occurring on existing operational models. The group was reduced to one man during the later part of the contract. It is estimated that a transfer of responsibilities to other groups would result in a net reduction of 40% of the manpower level required during the A7LB program. That is, the five people required during the Apollo Program could be reduced to three people, with one remaining in engineering and two reporting to CMO. During the operational phase, the level could be further reduced to one person in the CMO group.

GUIDELINES FOR FUTURE PROGRAMS:

Expand the responsibility of the CMO group to perform change activity functions which are normally performed by the engineering group.

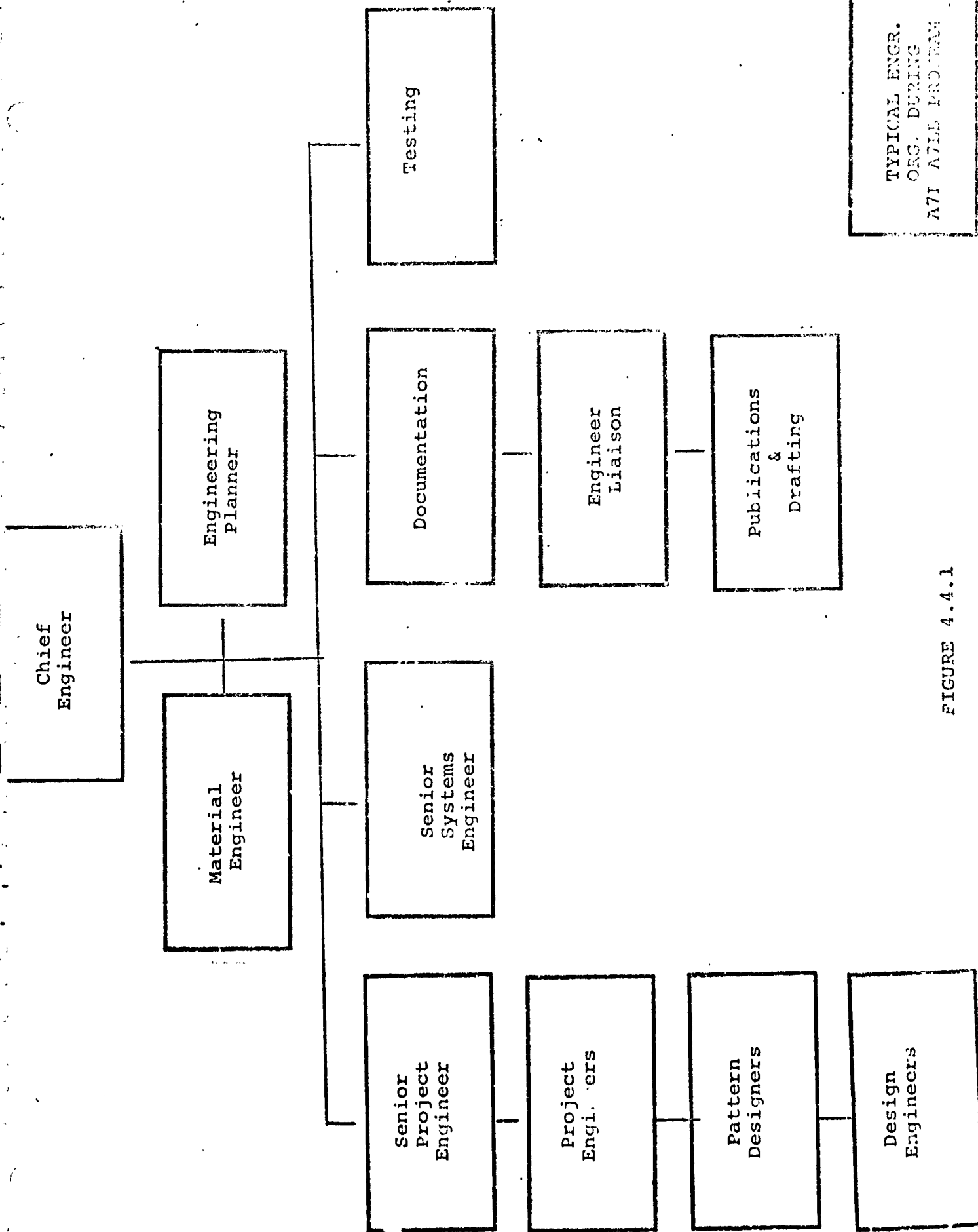
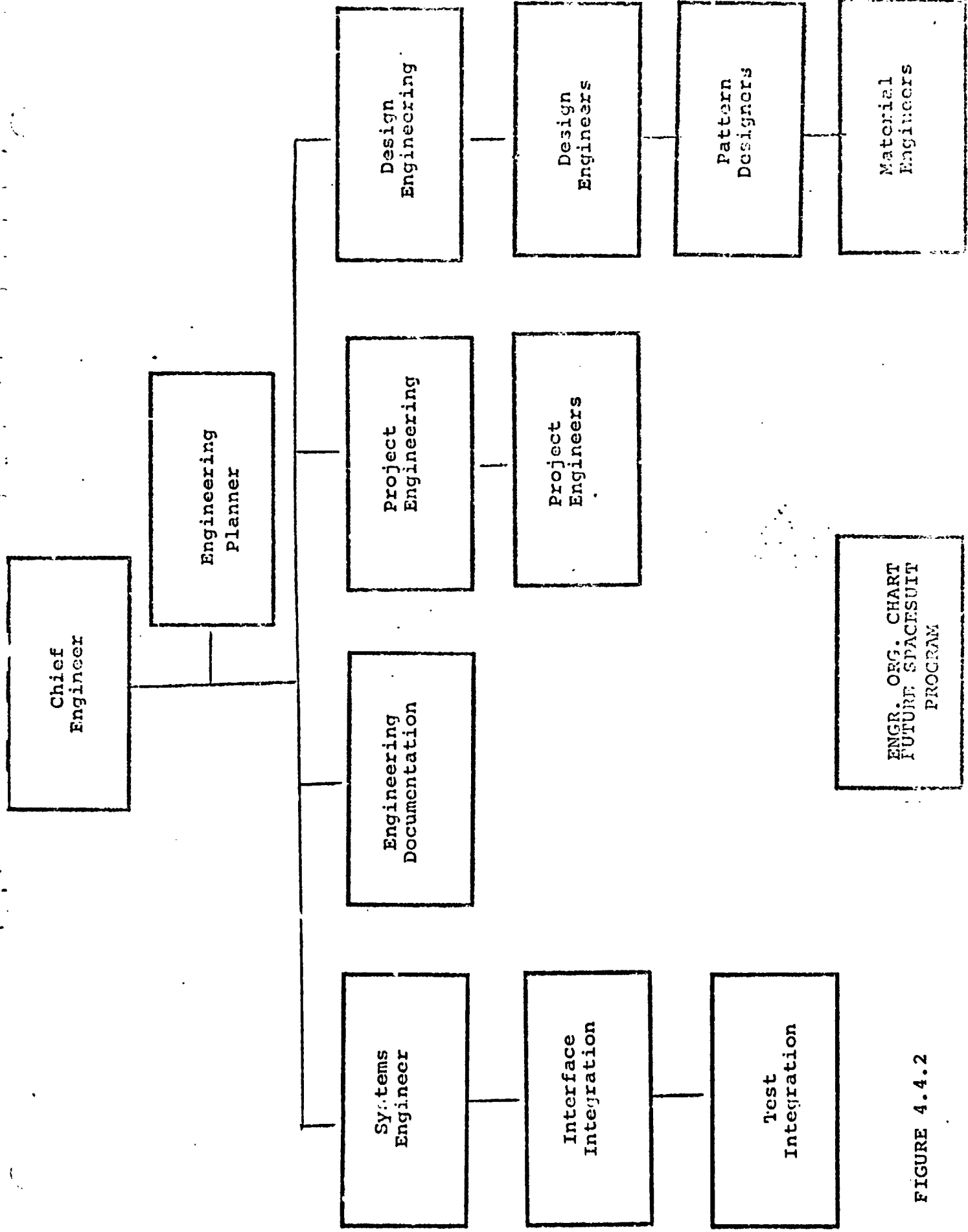


FIGURE 4.4.1





ENGR. ORG. CHART  
FUTURE SPACESUIT  
PROGRAM

FIGURE 4.4.2



# PHASING CHART, ENGINEERING ORGANIZATION 1970 - 1973

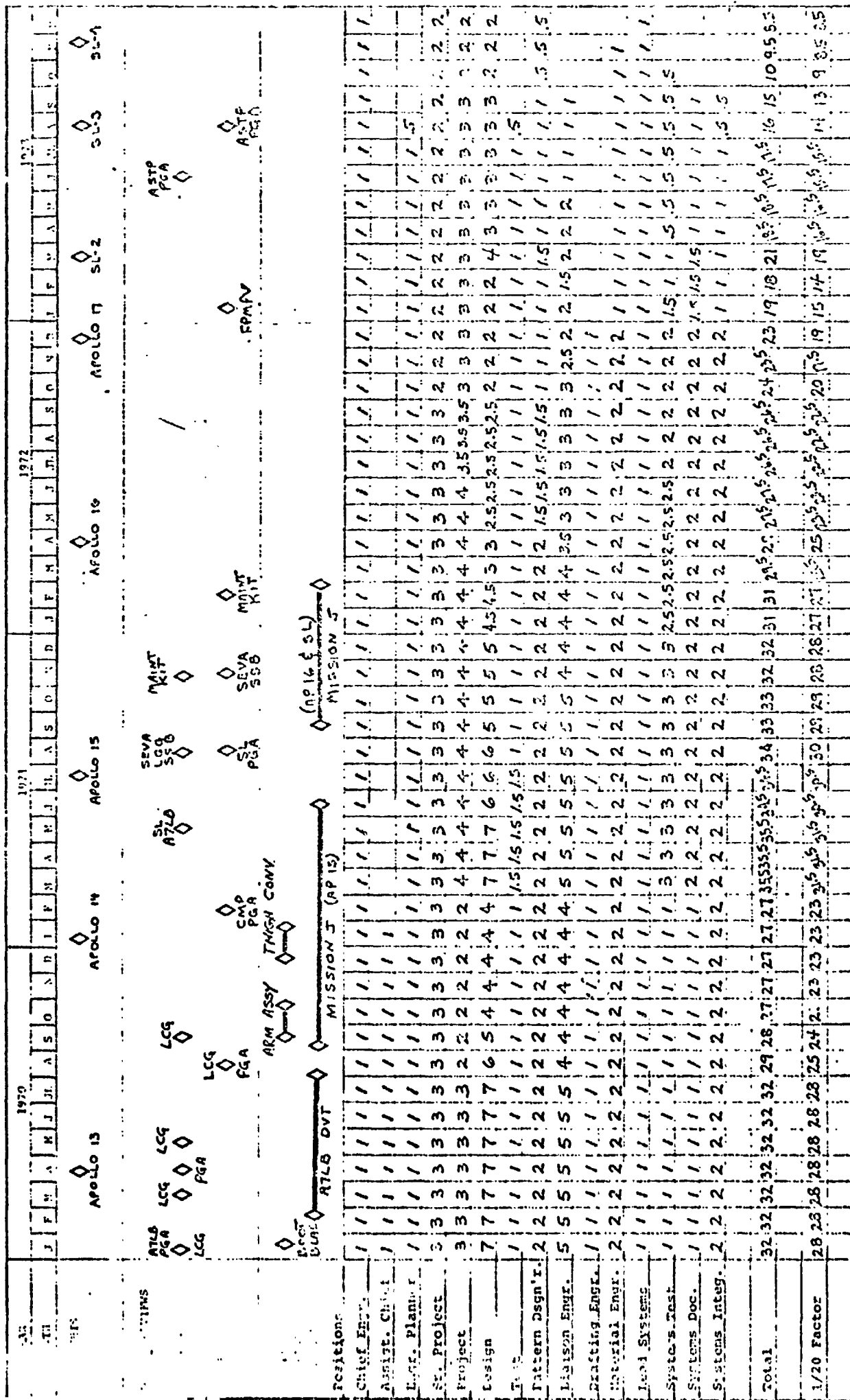


FIGURE 4.4.4

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<b>PROCESS</b> Processing Engr. Change to Drawings <input checked="" type="checkbox"/> MAN OR <input type="checkbox"/> MATERIAL						<b>SUMMARY</b> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th rowspan="2">ACTIONS</th> <th colspan="2">PRESENT</th> <th colspan="2">PROPOSED</th> <th colspan="2">DIFFERENCE</th> </tr> <tr> <th>NO.</th> <th>TIME</th> <th>NO.</th> <th>TIME</th> <th>NO.</th> <th>TIME</th> </tr> <tr> <td><input type="checkbox"/> OPERATIONS</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td><input type="checkbox"/> TRANSPORTATIONS</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td><input type="checkbox"/> INSPECTIONS</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td><input type="checkbox"/> DELAYS</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td><input checked="" type="checkbox"/> STORAGES</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="2">DISTANCE TRAVELLED (Feet)</td> <td colspan="2"></td> <td colspan="2"></td> <td></td> </tr> </table>						ACTIONS	PRESENT		PROPOSED		DIFFERENCE		NO.	TIME	NO.	TIME	NO.	TIME	<input type="checkbox"/> OPERATIONS							<input type="checkbox"/> TRANSPORTATIONS							<input type="checkbox"/> INSPECTIONS							<input type="checkbox"/> DELAYS							<input checked="" type="checkbox"/> STORAGES							DISTANCE TRAVELLED (Feet)						
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1 CMO receives ECO 2 CMO removes CCBD from desk & completes form 3 CMO obtains copies of affected drawings 4 CMO red-lines changes on drawings 5 CMO handcarries to Proj. Engr. dept. 6 Engr. dept. approves designated class of change 7 Engr. handcarries change package to CMO 8 CMO prep. ECO & assigns number 9 CMO takes ECO to Office Services 10 O.S. makes copies & distributes 11 CMO prep. request for release of masters 12 CMO delivers req. for release to O.S. 13 CMO takes ECO & dwg. pack. to drafting 14 Drafting receives package 15 Dftg. goes to dwg. crib to pick up dwg. 16 Drafting returns to drafting room 17 Draftsman revises drawing 18 Draftsman takes package to engineering 19 Proj. Engr. reviews & signs 20 Proj. Engr. returns pack. to CMO 21 CMO logs & submits ECO & dwg. pack. to govern.						1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21																																																												

DA FORM 334

(Formerly DA AGO)

REPLACES OCS FORM 391, 1 FEB 1951, WHICH MAY BE USED.

FIGURE 4.4.5

FIGURE 4.4.6

<u>QUALIFICATION ITEM</u>	<u>REASON FOR QUALIFICATION</u>	<u>DATES</u>	<u>ELAPSED TIME (MONTHS)</u>
A7L PGA	Mission C	1/25/68 8/29/68	7.0
Fluorel Boot Soles	Qual new material	8/1/68 9/19/68	1.5
A7L PGA	Mission C Prime	10/15/68 10/22/68	0.25
A7L PGA	Mission D	11/12/68 12/12/68	1.0
A7L Lunar Surface	Mission G	2/4/69 6/12/69	4.5
Large Wrist Disconnect (Apollo 11)	New Requirements	3/13/69 3/17/69	0.25
Arm Bearing (Apollo 11)	New Requirement	4/24/69 4/29/69	0.24
Boot Bladder (Apollo 13)	Flight failure	1/9/70 1/14/70	0.25
Arm Assembly and EV Glove (Apollo 14)	Redefinition of Cycle requirements	9/22/70 10/14/70	0.75
Redesigned Thigh Convolute (Apollo 14)	Qual Failure	12/3/70 1/14/71	1.5
A7LB PGA (Apollo 15)	Mission J	9/21/70 6/25/71	9.0
A7LB PGA (Apollo 16 & Skylab)	New Requirements (Young's Rocks) SL Boots and SEVA	9/3/71 2/21/72	5.75

Total Period - 49 months

Total Time in Qualification Testing - 32 months

Calendar Time in Qualification Testing - 29 months

SECTION V  
QUALITY



## 5.0 QUALITY

### 5.1 TITLE:

Traceability System

### OBJECTIVE:

To determine if a reduction in Quality and Reliability manpower can be realized through an evaluation of the Apollo/Skylab traceability system.

### APPROACH:

An evaluation of the traceability system has been performed by the use of flow charts to determine if modifications can be implemented to reduce paperwork and manpower without affecting system capabilities.

### BACKGROUND:

The traceability system was a manual Identification and Data Retrieval System meeting requirements of NPC-200-2 and is described in Flow Chart Q<sub>1</sub>.

The in-house documentation center, which contained the trace data, was also used as the central CEI file. It was the historical filing center, maintaining copies of all field generated TPS's and DR's, and functioned the same as field sites in that delivered end items could be processed in-house for rework and retrofit through TPS and discrepancy reporting systems. This system also provided tracking of Class II as well as Class I changes. The Documentation Center utilized full-time traceability/documentation clerks, documentation group leader, and a documentation engineer. In addition, 23 inspectors, 5 technicians and several quality engineers spent a significant amount of time related to the traceability system (approximately 10% for a CEI delivery rate of one every three days).

### PROBLEM:

A significant amount of manpower was required to maintain the traceability system.

BACKGROUND:

1. The system developed from a standard quality trace system and reliability data center (Ref. NPC-250-1) to one of providing a total historical/verification capability.

Ref. Flow Chart VI - As the flow chart indicates, the contractor quality documentation center received all field data and maintained central CEI and historical files. This required several traceability/documentation clerks to receive, file, update and store data. The Q & R department provided this manpower. These manpower requirements could be reduced if the task of filing, storing and retrieving data could be assigned to a Central Data Department. Q & R would still be responsible for verifying data being received by the central department.

2. Parts and materials were not categorized. This required the tracking of many non-critical parts or materials.

All parts and materials used on CEI's were treated equally with regards to material trace requirements. An evaluation of past data has shown that approximately 25% of the items need not have been traced past receiving inspection. Identification of critical and non-critical items must be completed as early as possible in order to effectively reduce all non-critical trace data during the production phase of the contract. However, evaluation has also revealed that even with criticality definition, the traceability flow (Ref. Flow Chart Q<sub>1</sub>) structure under a manual system can not be improved. The remaining trace of parts/materials would still require a closed loop system such as described in Flow Chart Q<sub>1</sub>. A 25% decrease in trace requirements will be significant in respect to time required to

transfer, log, accumulate, cross-post and file data.

An early establishment of a Critical Parts List would also be invaluable to quality engineering in performing vendor surveys, especially for those items that are long lead-times or sole source to assure they are fully acceptable to meet long term requirements of the contract. This would greatly reduce the probability of production downtime and schedule impact due to vendors' failure to meet full-term contract commitments.

3. Several different methods of tracking traceability data were used. This included shop orders, proprietary inspection route sheets and fabrication inspection route sheets.

Different forms, utilized by manufacturing, required various methods of tracing data to meet traceability requirements. Shop orders were used by model and machine shop personnel to record trace data where the drawing was the means of control for fabrication and acceptance. Fabrication inspection route sheets were used by all other production areas for acceptance and trace, except the dip room, where fabrication and acceptance was accomplished with the Proprietary Tables of Operation (T/O).

Regardless of the method used to fabricate and accept components, subassemblies or CEI's, a uniform method should be established as early as possible for meet all trace requirements. A reduction would be realized in filing because three different formats would no longer be required. Retrieval would be easier because there would be one system index. This system would eliminate the overlooking of a revision to any of the forms as a result of a CCA; i.e., changing the drawing and not the shop order.

4. Retrieval of data was time consuming because of the vast amount of parts and materials being traced. Development of a matrix for a continuing update capability for all parts/materials combinations and permutations proved to be impractical.

The situation could be alleviated by reducing the number of items requiring traceability beyond receiving inspection and a single fabrication acceptance format.

It is anticipated that sufficient quantities of critical items will still have to be traced. Therefore, a cost trade-off study of a manual versus computerized system should be undertaken.

5. A procedure was never established to identify who could request data.

This resulted in a considerable amount of overtime over the years in order to retrieve data and to prepare matrices and charts for data comparisons. Overtime was often required to perform normal daily duties that could not be performed as a result of requests for trace data. Some requests for data by contractor and NASA was either previously requested or of a non-critical nature. Quality and reliability personnel were handicapped in scheduling quality data center work as any request for trace data by NASA personnel was normally afforded top priority. While advantageous to have a contractor provide this service, it is also costly to NASA under a manual system. A procedure should be generated to control traceability access in order to reduce the possible non-critical or redundant data requests. The requests for data are often related to a specific problem but various departments require different information. If the requests were funneled through one source, the necessary information could be retrieved efficiently.

RECOMMENDED FUTURE SUIT PROGRAM METHOD:

GUIDELINES:

Method I - manual system. Streamline present traceability system by reducing requirements and transferring some tasks to a centralized data center.

The advantages would be reduction in manpower requirements, a reduction of paperwork and a faster retrieval capability.

Using a centralized data center for filing and storing trace data, quality assurance will only monitor and verify trace data incoming to the center. This will require a full-time QC representative in central data system or several representatives having this duty as part of their overall function. Class II ECO information will not be traced. This will result in a smaller fabrication inspection route sheet system which will reduce the quality representative's verification time as well as paper work requiring filing and storing. Future programs should have a specific procedure for how and who may request traceability data in order to reduce manpower requirements for attaining non-essential or redundant requests for traceability data.

The traceability requirements should be established. This baseline would include information required for such events as to support design studies, malfunction investigations, material review board activity, defect analysis and unsatisfactory reports corrective actions. A system could then be developed which could be satisfactorily operational with a minimum amount of changes.

RECOMMENDED GROUND RULES FOR MANUAL SYSTEM:

1. Must function under NPB 5300.4 document.
2. Non-critical parts are not to be traced past receiving inspection.
3. Central data center will handle all filing, storing and retrieval of traceability data and will verify data.
4. All trace data is to be recorded by a single system.

Method II - Computerized system - if the future contractor has access to computerized system, this could reduce the traceability manpower requirements substantially.

The computer could be programmed to follow guidelines identified by trace flow chart Q<sub>1</sub>.

The advantages, other than a reduction in manpower requirements, would be faster retrieval in response to any requests for data and less control on who may use this service. Class II changes may still be tracked without additional manpower requirements. As-built configurations can be compared to as-authorized configurations anywhere in the production process.

GROUND RULES FOR COMPUTERIZED SYSTEM:

1. Compliance with NHB 5300.4.
2. Quality assurance must have effective controls to verify all data necessary to meet requirements.
3. The contractor must have central data center to handle all filing and storing of data.
4. All trace data is to be recorded by a single system of reporting.

## 5.2 TASK TITLE:

### Inspection and In-Process Verification

#### OBJECTIVE:

Reduce amount of discrepancy paper, inspection manpower and production down-time.

#### APPROACH:

Evaluate present system of production, inspection and discrepancy reporting to identify major problems that resulted in defects, production down-time, excessive inspection time and overtime. This evaluation will concentrate on the in-process fabrication and testing acceptance.

#### BACKGROUND:

Apollo/Skylab suit inspection system met requirements of NPC-200-2. It was implemented to assure a product quality consistent with the level of confidence necessary for a man/space rated system.

The inspection and testing system was designed to assure that end items met all pre-delivery acceptance criteria. Quality established a very detailed inspection system. Components and sub-assemblies were inspected at every point where characteristics could not be verified at a later operation. Some components and most sub-assemblies were not tested until after integration of CEI. These component/sub-assemblies had to meet strict inspection standards since test failures affected shipping schedules, fabrication of new assemblies, overtime and malfunction reports.

Quality inspection was required to maintain the production flow under this system of 100% quality inspection verification. Inspection manpower could not be reduced by delegating portions of inspection to manufacturing, because defects may not have been detected until CEI testing. Then investigation at the CEI level for cause and corrective action at the component/sub-assembly level would have been difficult, or impossible and would have had greater impact on manufacturing scheduling.

The normal ratio of inspectors to production operators was approximately one to eight. This caused an inspector to

have as many as seven or eight different articles to inspect at one given period. This resulted in manufacturing down-time awaiting the return of the article from inspection. Even though production flow was set-up in an assembly line sequence, many times an operator had nothing to do until the article was returned by inspection. Approximately 90% of all in-process inspection was of an in-line nature. This meant that the inspection was accomplished while the article was being fabricated and only 10% of inspection occurred at article's completion. This added a considerable amount of (additional) flow time to fabricate a complete sub-assembly or component.

Articles presented to inspection which were of a non-conformance nature required the initiation of a reject tag. It took an average of one hour to write, process and accept disposition, for each reject tag before an article could be processed to the next fabrication step. In the last four years of the program, approximately 30,000 reject tags were generated. This averaged out to one inspector writing two reject tags per day. There were 1,600 material review board actions in the last four years which required an average of four hours to evaluate the cause of problem and the corrective action to preclude the recurrence. A large amount of the time involved quality, design, manufacturing and government engineers to satisfactorily process material review board actions.

PROBLEM:

1. Lost production and program time due to the amount of in-line inspection.

BACKGROUND:

A. Due to the lack of capability to adequately test components and sub-assemblies separately, in-line inspection became an absolute essential. No other method would assure that the components or sub-assemblies met all acceptance criteria for end item use until final testing and acceptance of completed CEI.



This was a costly method of assurance. Delegation of even a small percentage of acceptance characteristics to manufacturing was considered unacceptable since quality assurance was charged with the responsibility of final item acceptance to assure design reliability.

One way to reduce in-line inspection on future contracts, without sacrifice of confidence in the end item, is to design components and sub-assemblies for testing and acceptance at the component and sub-assembly level. This will allow a reduction of production down-time by decreasing the amount of in-line inspection required. Delegation of various in-process inspection responsibilities could then be made to manufacturing personnel. In order to delegate inspection responsibility, operator certification must be implemented. It must be made a part of the hiring practice that a person must be able to be certifiable. All tools required to insure good quality from the operator must be made available to insure that any poor quality is not the fault of management. (Example: detailed manufacturing specs, discrepancy feed back to operator level, proper equipment, incentive and motivation.)

Only critical inspection for component/sub-assembly acceptance should be performed by quality personnel. All manufacturing inspection will have to be monitored on a scheduled basis as an audit function of Quality engineering. This will also provide a check of operator's certification status.

Any test failures, resulting from poor quality on an operator's part, would require an immediate re-evaluation of operator's certification classification.

It must be clearly understood that under an operator certification program, defects may occur which will affect component acceptance testing, the same way as defects affected final CEI testing with 100% quality inspection. Schedules would still be impacted by sub-assembly or component failures, but not to the degree of a failure encountered on completed CEI's.

The system must be established to produce the same confidence level, under delegated inspection on the sub-assembly level, that existed with 100% inspection on the completed CEI level. This is an absolute necessity, or manufacturing's certification creditability will be questioned in evaluations of malfunction reports, single point failures, etc. Once an (malfunction or defect) analysis seriously questions this method of inspection, no amount of explanation will ever remove this as a possible cause of defect or malfunctions. A corrective action to implement 100% inspection at a component/sub-assembly level would occur very quickly, eliminating any reduction in costs.

Production cycle time standards allowed 12% of total flow time for inspection during fabrication. This figure actually amounted to approximately 35%. This system allows a certain percentage of operators to present items to inspection when an inspector has several items to inspect in order to create some free time before their item is returned. Coupled with down-time for rejections this created an increase in the production cycle.

## II. Quantity and time required to process discrepancy paperwork.

- A. Sampling of discrepancy reporting paperwork over the length of the contract has revealed several significant facts.
  - 1. 25% to 30% of discrepancies written were of a minor nature or cosmetic requiring no further action.
  - 2. 35% to 40% of discrepancies written were of an obvious non-conformance nature requiring scrap, rework or repair.
  - 3. Remaining 30% to 40% were of a nature that required design engineering interpretation as to scrap, rework or material review board action for "use-as-is" or repair not covered by authorized repair procedures.

As stated before, approximately 30,000 reject tags were generated over the last four years of the program. It is very significant to mention that the four years previous to A7LB/Skylab produced nearly twice the amount of reject tags (approximately 60,000). A significant reduction in the total amount of rejects can be attributed to advancement of the "state of-the-art" and accumulation of past history to evaluate reject tags without as much design interpretation.

This evolutionary process must be considerably shortened if any cost reduction efforts are to be realized.

Evaluation of effectiveness of reducing non-conforming paperwork, defects and positive disposition ability has shown that quality could not be built into the product especially after fabrication of first article qualification unit.

Dispositioning of non-conformance by manufacturing and quality engineering, was very difficult without continuous aide from design engineering. All manufacturing specifications were of a general nature which gave inspection very few guidelines on what was rejectable and what was of a minor nature, not requiring generation of non-conforming paperwork. Specifications lacked definitions to allow manufacturing engineers to make decisions effecting disposition of non-conforming items. Inspectors had to reject everything of a questionable nature, because there were insufficient guidelines for them to accept minor conditions. This resulted in a production delay while evaluation was being made.

Design engineering was reluctant to change acceptance criteria after the suit was qualified. Recurring non-conformances were dispositioned "use-as-is" but specification changes for future articles were rarely changed. Design engineering rationale was valid, in that multiple changes of acceptance criteria would effect the design and reliability of the previously qualified suit configuration.

Obviously defects occur. It is the amount of defects, reporting methods and disposition of non-conformance that have significant program impact. Unless effort is applied in the earliest design stages to evaluate these problems, the most effective Quality tool "Cost Reduction" cannot be adequately utilized. Areas for this evaluation are (1) accurate tolerance study to set realistic manufacturing tolerances, instead of creating tolerances that exceed safety margins, (2) establish specifications that allow manufacturing engineering to make positive dispositions of non-conformances, (3) evaluate all potential cosmetic and minor defects to determine those that will not require generation of discrepancy paperwork.

The above tasks require sufficient manpower loading during the design concept of future programs. Well defined goals must be established early in the program to realize a long-term cost reduction program.

RECOMMENDED FUTURE SUIT PROGRAM METHOD:

GUIDELINES GENERAL:

Early involvement by Contractor's, Manufacturing and Quality departments is necessary. All previous causes of non-conformance paperwork, detailed in-process inspection, Manufacturing Engineering's ineffectiveness in decision making and excessive design engineering involvement during the production phase will not be significantly improved unless Design, Manufacturing and Quality Engineering, together, establish realistic goals to form a solid foundation that will assure the most efficient means of operation.

GUIDELINES SPECIFIC:

- A. The Manufacturing specifications and procedures must provide the Manufacturing Engineer with the capability to evaluate and disposition non-conformance. Manufacturing and Quality Engineering must be exposed to pre-production fabrication methods.

A basic cause and affect analysis of discrepancies encountered during the design phase will serve as a solid base for establishing disposition of future production non-conformances. Manufacturing and Quality Engineering will have an opportunity to observe and evaluate pre-production fabrication, and working with the design engineer, determine realistic production acceptance criteria.

Manufacturing engineers, aided by Quality and Design Engineers, will collect data necessary to generate the basic manufacturing specification that will be used during the production phase.

Specifications will be designed to allow update for actual production problems as they are encountered.

This will result in the ability of the Manufacturing Engineer to evaluate the majority of non-conformities encountered during the production phase without continued aid from Design Engineering. This will also reduce the "design interpretation" category of reject tags, which represented 30 to 40% of total discrepancies.

Manufacturing specifications and procedures must classify defects. Major and minor defect classification plays an important part in the production phase of the product. Failure to establish the defect classification during the design phase of the product will produce wide range interpretation of accept/reject criteria during the production phase of the program. Inspectors will reject any products not specifically covered by specifications or procedures causing delays for evaluations and disposition of questionable rejects.

There is no way to identify and categorize all possible defects during the design phase of the product. Here, however, cosmetic or minor conditions not requiring rejection, minor defects dispositioning and major defects requiring complete engineering involvement, should be evaluated. The effort for improving the manufacturing specifications and procedures for use must be initiated during the preliminary design stage. This should result in significant reduction of rejects involving "cosmetic" and other minor conditions which represented 25 to 30% of all rejects.

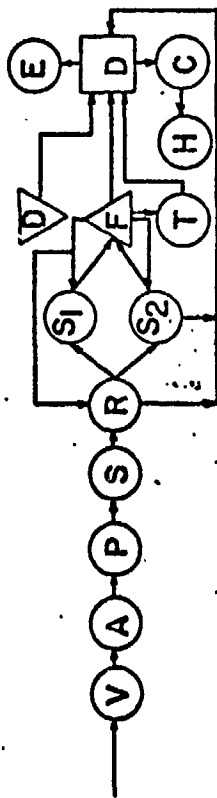
Manufacturing specifications and procedures must provide workmanship standards to guide manufacturing and inspection functions. Many times acceptance criteria cannot be expressed as a tolerance. In these cases, pictures or sample items of what constitutes an acceptable condition are preferable to written criteria. Even when acceptance is expressed by a tolerance, visual aids are helpful for comparisons.

This should result in better awareness by manufacturing operators to acceptance standards; it will also reduce the amount of non-conformities presented to inspection. This will reduce the "obvious defects" category which comprised 35 to 40% of total reject tags and decrease inspection interpretation of acceptance/rejection criteria.

The contractor must expand the Operator Certification Program. This guideline would be most effective if acceptance testing is implemented at the subassembly level. This concept must be applied in order to confidently delegate certain

quality acceptance criteria to other departments. This Operator Certification Program must be a probation period to properly evaluate whether an individual can meet the certification requirements. To be certified, they must be capable of using all tools provided to insure a Quality product. They must be capable of reading and understanding all manufacturing specifications and procedures pertaining to the product such as Table of Operations and drawings. They must display more than just the ability to perform fabrication operations, they must show a Quality awareness. Diligent pursuance of this program will produce a reduction of up to 60% of in-line inspection which will result in less down-time waiting return from inspection, also a significant reduction of obvious defects which comprise 35 to 40% of all previous defects, and a reduction in Quality inspectors required to support production.

# **PARTS AND MATERIALS TRACE FLOW CHART I, GENERAL FLOW**



- (V)** VENDOR SURVEYS
- (A)** APPROVED VENDOR LIST
- (P)** PURCHASE ORDER (PURCHASING)
- (S)** SOURCE - VENDOR, SUBCONTRACTOR GOVERNMENT FURNISHED ITEMS
- (R)** RECEIVING INSPECTION
- (S1)** CONTRACTOR STORES
- (S2)** GOVERNMENT BONDED STORES
- (F)** FABRICATION AREAS - MACHINE SHOP, MODEL SHOP, DIPROOM, HARD GOODS ASSEMBLY, PRODUCTION AND FINAL ASSEMBLY
- (T)** PRELIMINARY DELIVERY ACCEPTANCE TESTING
- (D)** DEPOT QUALITY DOCUMENTATION CENTER
- (E)** ACCEPTANCE DATA PACKAGE
- (C)** CENTRAL END ITEM FILE
- (H)** HISTORICAL FILE
- (D)** FIELD QUALITY DOCUMENTATION CENTER

AREA OF ACTIVITY NUMBER OR LETTER OF FLOW SEQUENCE  
 BASE FLOW  
 FEEDBACK FLOW

## **CHART I GENERAL FLOW SEQUENCE**

Quality Engineering performs vendor survey to assure that vendor can meet traceability requirements. Quality Engineering issues approved vendor list to Purchasing Department. Quality Engineering reviews purchase order to assure proper traceability requirements and vendor is on approved list.

Purchase order is issued to vendor. Vendor sends ordered item to Receiving. Receiving Inspection receives vendor items, sub-contractor parts or government furnished items. Receiving Inspection sends item to applicable Stores area and forwards traceability data to Quality Documentation Center.

Fabrication station receives item from Stores. Forwards completed item back to Stores or Receiving, another fabrication area or final assembly. Trace data sheets completed are forwarded to Quality Documentation.

Documentation Center receives all trace data from all areas including field sites. List required information in acceptance data package and files all traceability data not included in AUP in Central CEI file.

All data is filed in Historical File for length of time determined by contract.



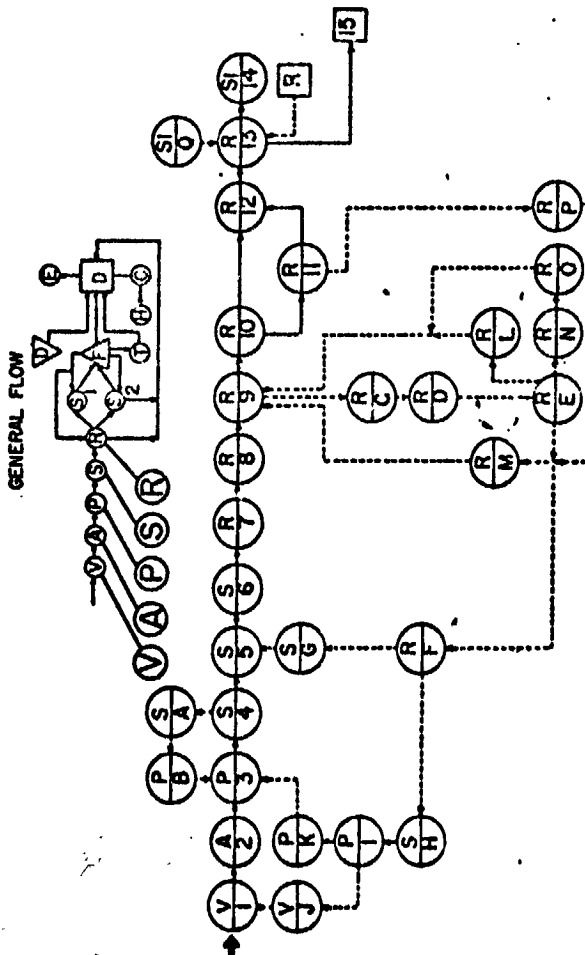
# CHART II, CONTRACTOR PROCURED VENDOR SURVEY THROUGH RECEIVING INSPECTION

CHART II

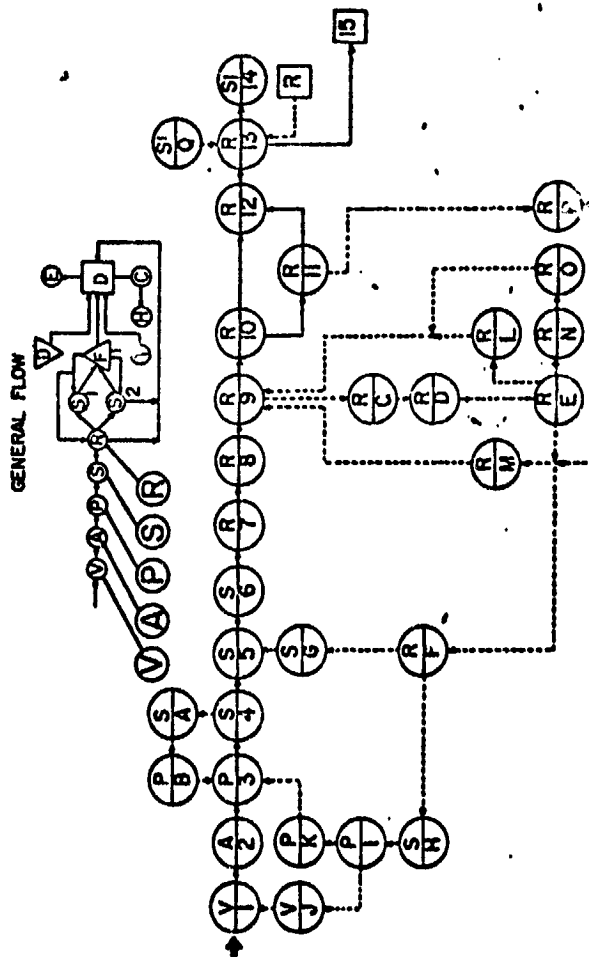
## VENDOR SURVEY THROUGH RECEIVING INSPECTION FLOW SEQUENCE

Basic flow - contractor procured items

1. Quality engineer performs vendor survey to assure ability to provide trace information.
2. Quality issues approved vendor list to Purchasing.
3. Purchase Order reviewed by Quality. Trace code made part of Purchase Order.
4. Vendor receives Purchase Order.
5. Vendor meets all traceability requirements. Source verification is performed by Contractor and/or Customer when required.
6. Parts or materials along with traceability requirements of Purchase Order are shipped to the Contractor.
7. Contractor Quality Receiving Inspection receives parts or material from Vendor.
8. Receiving Inspection makes inspection/traceability folder or updates folder if parts or materials is a reorder. Folder identifies parts or materials by Vendor, part number identification and Purchase Order number. Lot number is assigned or serial number is recorded.
9. Receiving Inspection reviews traceability data against Purchase Order requirements.
10. Receiving Inspection verifies that trace data is accurate and meets Purchase Order requirements.
11. Parts or materials are inspected and/or tested when required.
12. Testing and/or inspection is acceptable and accurate against Vendor certifications.
13. Accept/traceability ticket is generated having all necessary



## CHART II, CONTRACTOR PROCURED VENDOR SURVEY THROUGH RECEIVING INSPECTION



information for traceability to Receiving Inspection.

14. Parts or materials are sent to contractor stores area.

15. Purchase Orders, certifications and lot/serial number

identification are forwarded to Quality Documentation Center.

### Discrepancy Feedback Flow

A. Vendor can't meet trace requirements per Purchase Order and requests joint review with Contractor.

B. Purchase Order to clarified, changed or cancelled.

C. Review of Vendor trace data reveals lack of complete data, incorrect data or no traceability data in accuracies per Purchase Order. Parts or materials are rejected.

D. Parts or materials are segregated in secured holding area awaiting evaluation as to disposition.

E. Evaluation by Quality and/or Engineering determines,

F. Traceability requirements can't be met. Return to Vendor for replacement or credit.

G. Vendor agrees to replace items with Purchase Order requirements and gives credit.

H. Vendor chooses not to supply parts or materials in the future.

I. Purchasing is informed that vendor can't demonstrate ability to supply certified parts or materials and chooses not to accept Purchase Orders of this nature in the future.

J. New Vendor must be located.

or

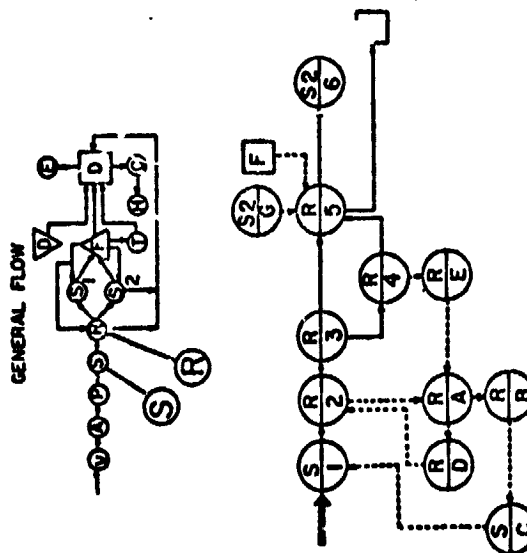
K. Parts and materials are to be purchased from another approved Vendor.

or

L. It's advantageous to test parts or materials in-house.



# CHART III GOVERNMENT FURNISHED ITEMS RECEIVED



## CHART III PARTS & MATERIALS TRACE FLOW GFE THROUGH RECEIVING INSPECTION

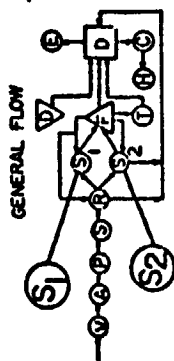
### Basic Flow - Government Furnished Items

1. GFE received from source.
2. Items are reviewed by Quality and Government representatives.
3. Traceability is verified as being accurate.
4. Parts/materials are tested when require .
5. Contractor Quality issues accept/traceability tag indicating GFE and updates Government Identification tag.
6. Parts/materials are forwarded to Government bonded stores.
7. Shipping documents are forwarded to QC Documentation Center for final review and filing.

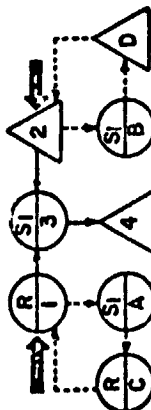
### Discrepancy Feedback Flow

- A. Traceability information is missing or incorrect.
  - B. Traceability data can't be used as received. Return to source.
  - C. Original source to supply replacement.
- or
- D. Traceability data can be used "as is" with Government concurrence.
  - E. Traceability data can't be verified.
  - F. Shipping documents returned to Receiving by QC Documentation, due to trace inaccuracies.
  - G. Parts/materials returned to Receiving Inspection - accept/traceability ticket information has inaccuracies.

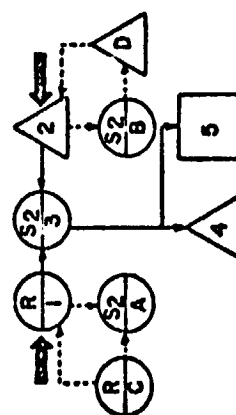
# CHART IV STORES AREAS



## CONTRACTOR STORES



## GOVERNMENT STORES



## GOVERNMENT STORES CHART IV

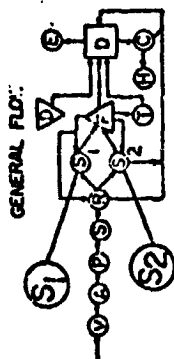
### Base Flow - Government Bonded Stores

1. Receives parts or materials from Receiving Inspection.
2. Receives fabricated or reworked components or sub-assemblies from Production area.
3. Trace data is verified accurate and accepted in government Stores with government verification.
4. Parts/materials are only issued from Government Stores area with customer approval.
5. Completed test preparation sheets, discrepancy reports and Receiving documents are forwarded to Quality Documentation Center.

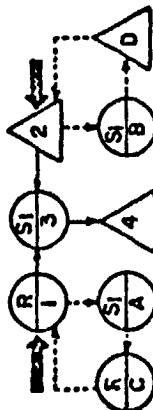
### Discrepancy Feedback Flow - Government Bonded Stores

- A. Parts or materials returned to Receiving Inspection due to inaccuracies on accept/traceability ticket.
- B. Components or sub-assemblies returned to Production area due to inaccuracies on accept/traceability ticket.
- C. Receiving Inspection corrects inaccuracies.
- D. Production corrects inaccuracies.

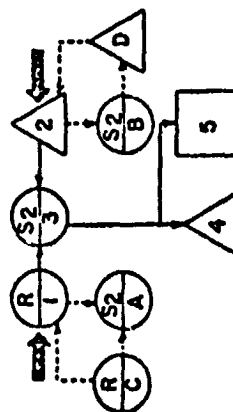
# CHART IV STORES AREAS



## CONTRACTOR STORES



## GOVERNMENT STORES



# CHART IV PARTS & MATERIALS TRACE FLOW STORES

## Base Flow - Contractor Stores

1. Receives parts or materials from Receiving Inspection with accept/traceability ticket.
2. Receives components and sub-assemblies with accept/traceability ticket from Production areas.
3. Verifies that information on accept/traceability ticket is accurate and accepted in Stores area.
4. Releases parts/materials, components or sub-assemblies to Production and verifies that items issued meet requirements or production order.

## Discrepancy Feedback Flow - Contractor

- A. Returns parts or materials to Receiving Inspection due to traceability inaccuracies.
- B. Returns components or sub-assemblies to Production area due to traceability inaccuracies.
- C. Receiving Inspection corrects inaccuracies.
- D. Production area corrects inaccuracies.

# CHART V FABRICATION AREAS

CHART V

## FABRICATION AREAS FLOW SEQUENCE

### Base Flow - Machine Shop

1. Inspector receives raw materials from Stores.
2. Verifies that trace data is correct per Shop Order (S/O).
3. Makes out accept/traceability ticket for completed item.
4. Forwards component to Receiving for completion of acceptance.
5. Forwards completed component back to Stores with accept/traceability ticket.
6. Forwards completed S/O to Quality Documentation Center.

### Discrepancy Feedback Flow

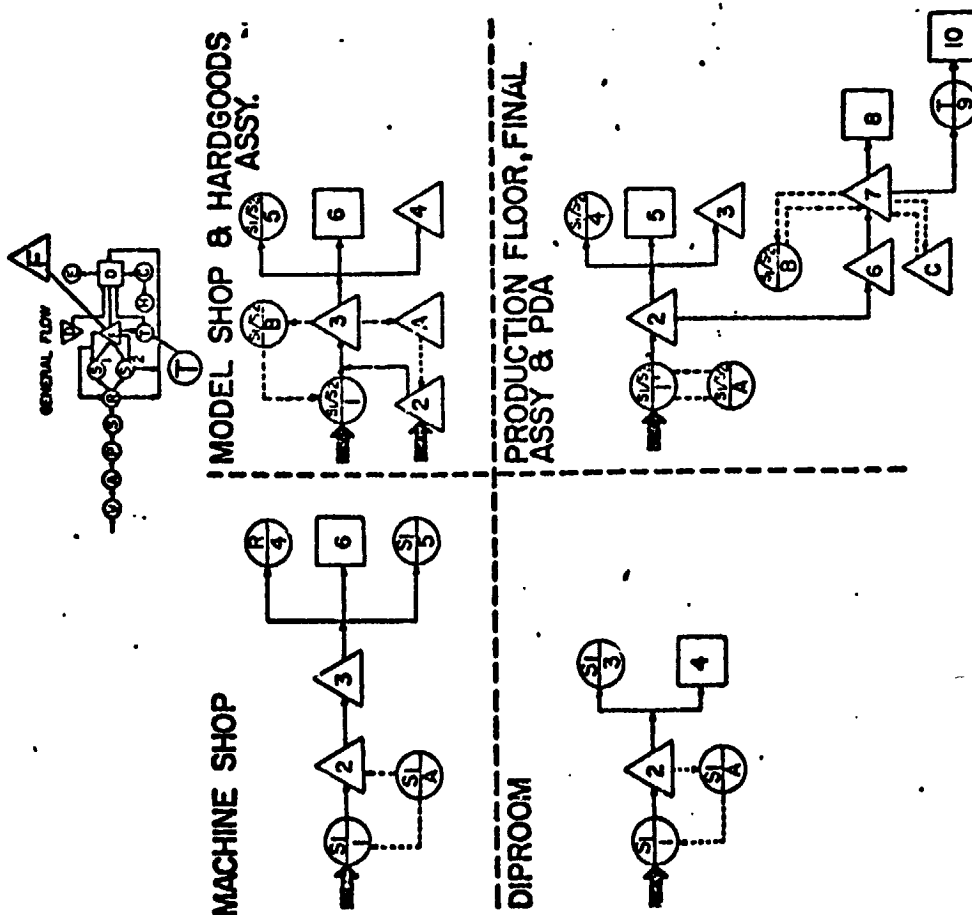
- A. Raw materials returned to Stores due to traceability inaccuracies.

### Model Shop and Hardgoods Assembly Basic Flow

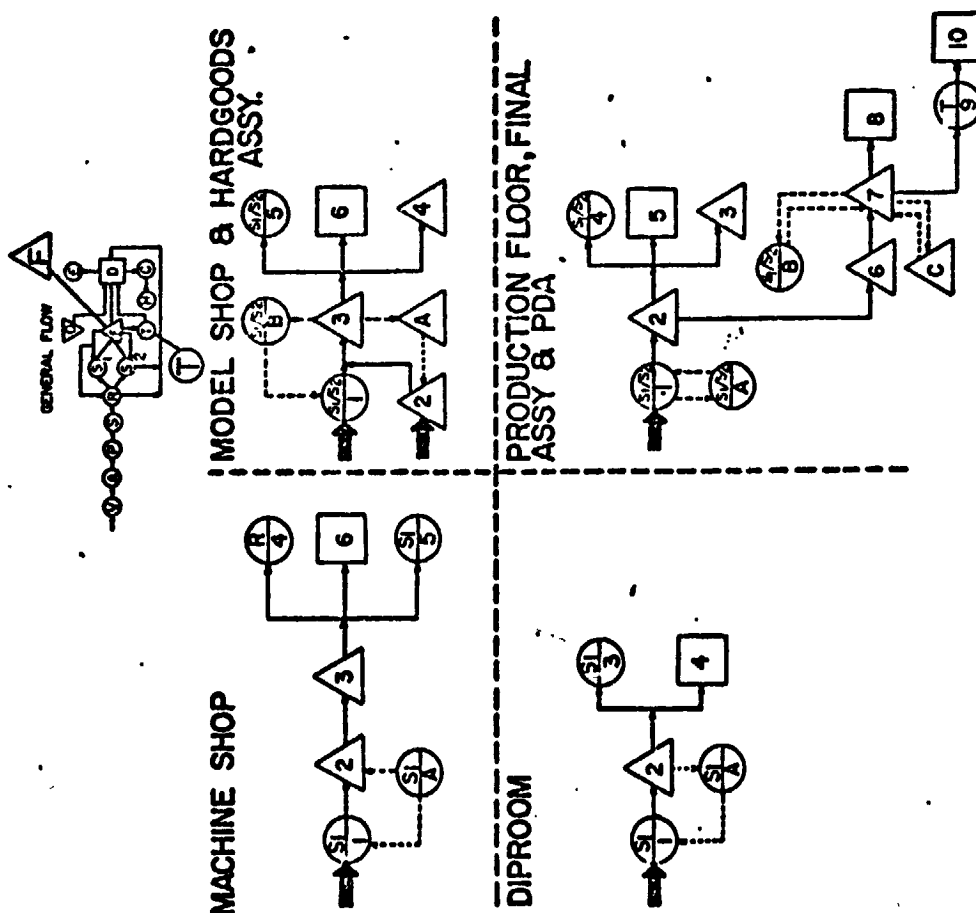
1. Parts or materials received from Stores.
2. Parts received from other production areas.
3. Verifies that parts or materials trace data is accurate.
4. Forwards items to next production area along with uncompleted paperwork.
5. Forwards completed items to Stores with accept/traceability ticket.
6. Forwards completed S/O or fabrication inspection route heats (FIRS) to Quality Documentation Center.

### Discrepancy Feedback Flow

- A. Parts or material are returned to Stores area due to traceability inaccuracies.
- B. Parts or material are returned to Production area due to



**CHART V  
FABRICATION AREAS**



traceability inaccuracies.

Diproom Basic Flow

1. Raw materials received from Stores.
2. Verifies that materials trace data is accurate.
3. Forwards completed component with accept/traceability ticket to Contractor stores.
4. Forwards completed proprietary inspection route sheets (PIRS) to Quality Documentation Center.

Discrepancy Feedback Flow

1. Raw materials returned to Stores due to traceability inaccuracies.

Production Floor, Final Assembly and PDA Basic Flow

1. Parts or materials received from Stores.
2. Verifies trace data is correct per FIR's.
3. Forwards item and uncompleted FIR's to next production area for completion of sub-assembly.
4. Forwards completed item to stores with accept/traceability ticket.
5. Forwards completed FIR's to Quality Documentation Center.
6. Forwards completed item to final assembly with accept/traceability ticket.
7. Verifies all components sub-assemblies and materials on final assembly FIR's.
8. Completed final assembly FIR's package is forwarded to Quality Documentation Center.
9. Forwards completed end item to predelivery acceptance - -



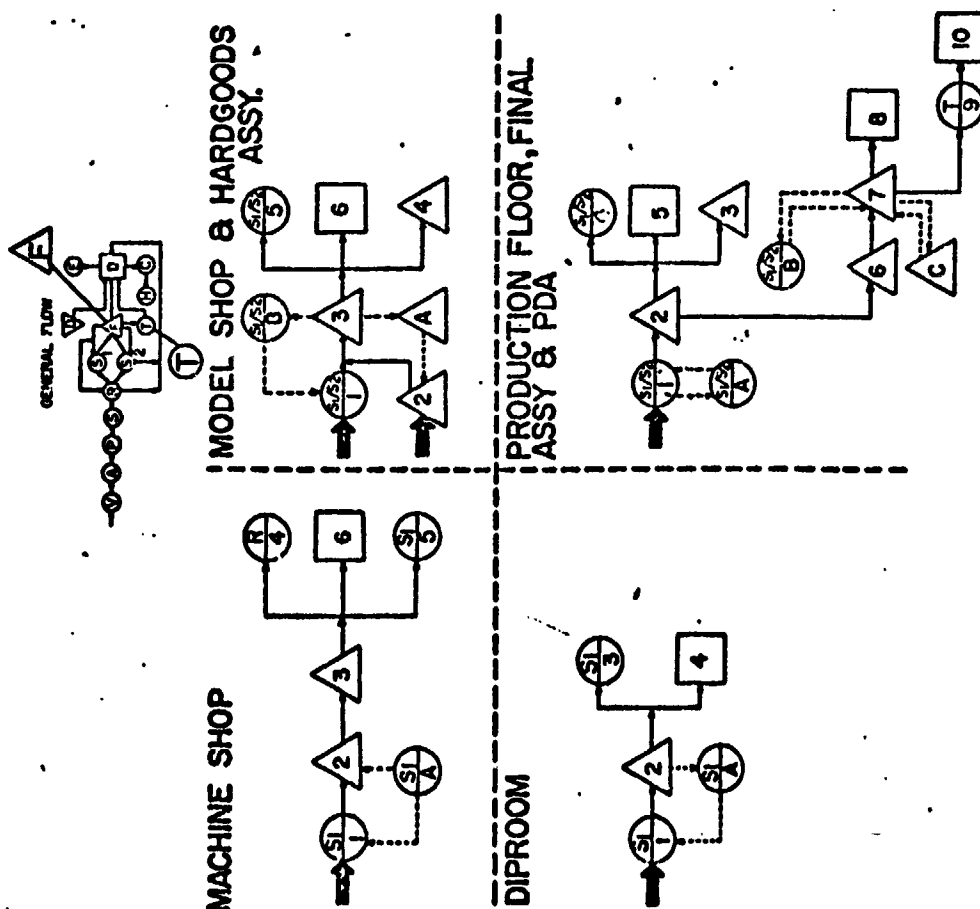
# CHART V FABRICATION AREAS

testing (PDA) with accept/traceability ticket.

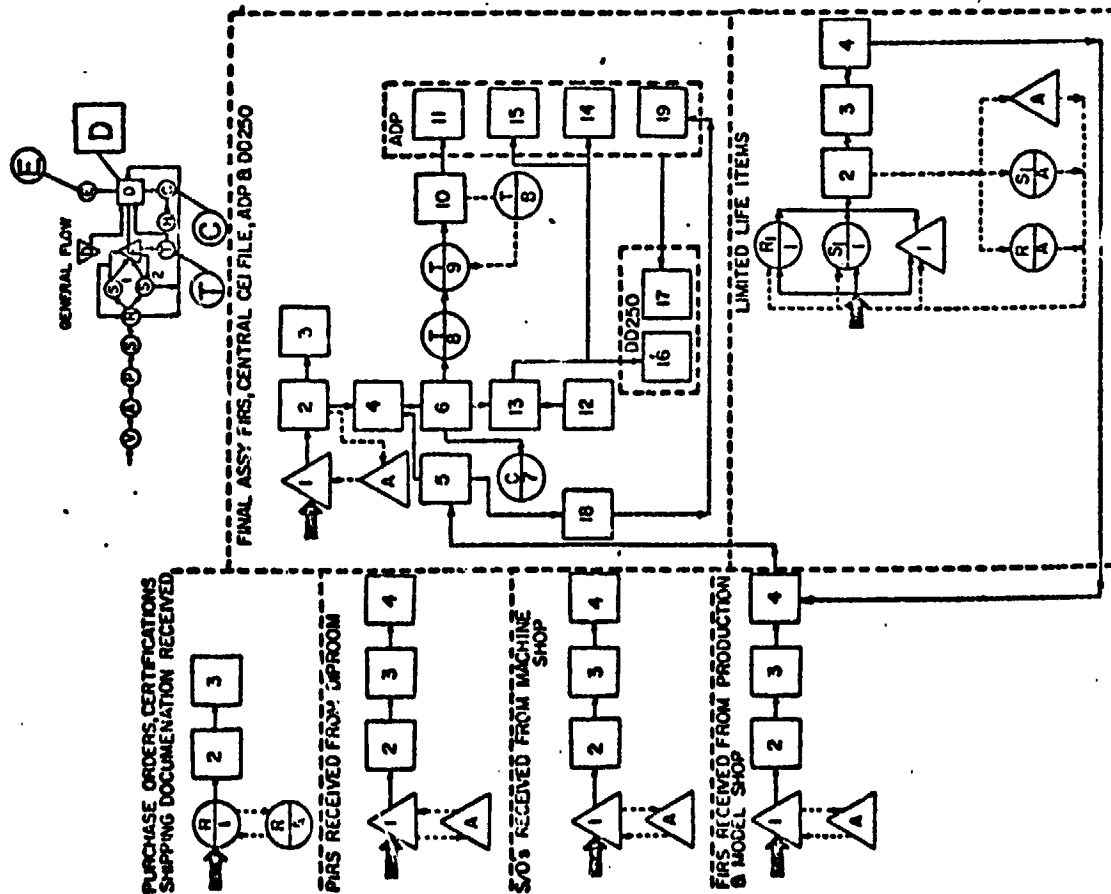
10. PDA report forwarded to Quality Documentation Center.

## Discrepancy Feedback Flow

- A. Parts or materials returned to Stores area due to traceability inaccuracies.
- B. Sub-assemblies returned to Stores area due to traceability inaccuracies.
- C. Sub-assemblies returned to Production area due to traceability inaccuracies.



# **CHART VI** **QUALITY DOCUMENTATION CENTER,** **ADP (PRIOR TO DD250 d) &** **CENTRAL CEI FILE**



## **CHART VI**

**QUALITY DOCUMENTATION CENTER, ACCEPTANCE DATA PACKAGE AND CENTRAL CEI FILE FLOW SEQUENCE (PRIOR TO DD250)**

**Purchase Orders, Certifications and Shipping Documentation received**

1. Copy of Purchase Orders, Certifications and Shipping Documentation forwarded from Receiving Inspection with serial number or lot number identification.
2. File card made by part number, dash number, serial number or lot number and nomenclature.
3. Purchase Order, certifications and shipping documents filed by Vendor and numerically by Purchase Order number.

### Discrepancy Feedback Flow

A. Purchase Order, certifications and shipping documents are returned to Receiving Inspection due to traceability inaccuracies.

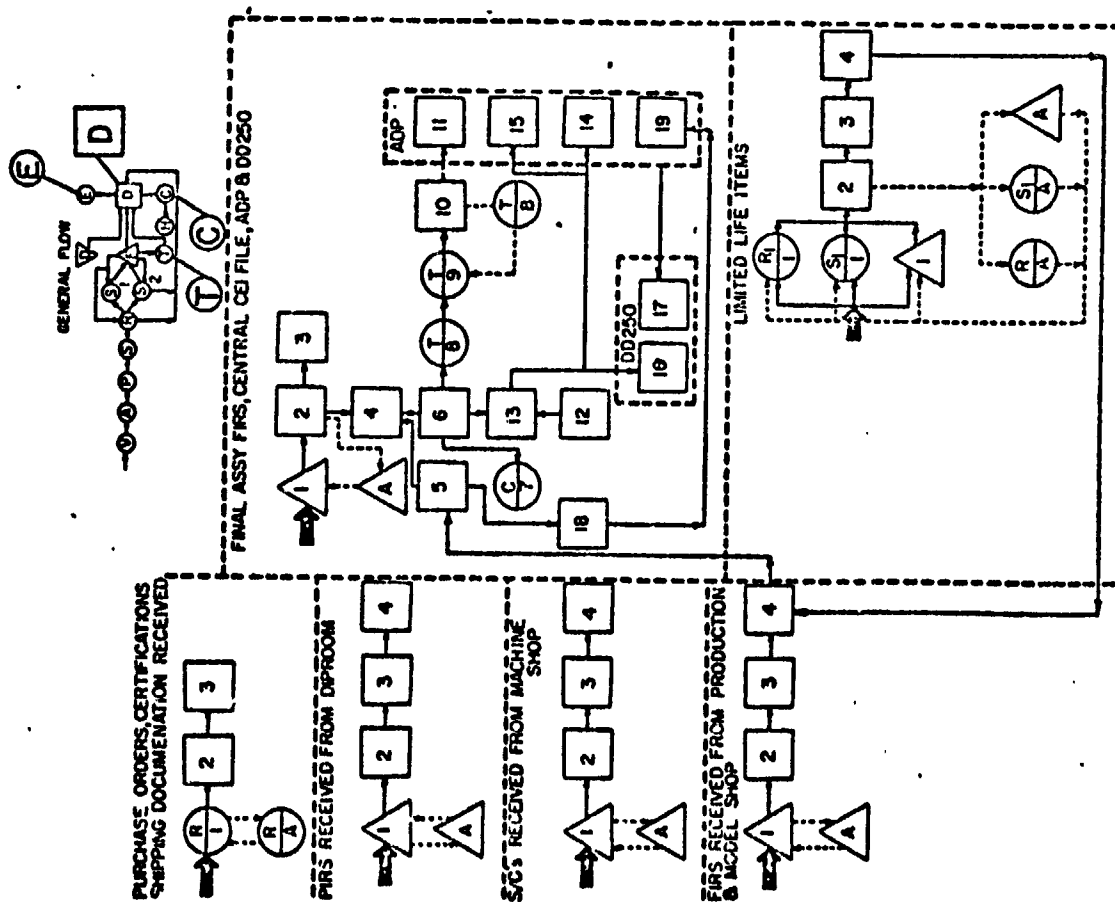
**Proprietary Inspection Route Sheets from Diproom**

1. PIRS received from Diproom.
2. Parts/materials list verified as accurate.
3. Material trace data is recorded on file card.
4. Folder made by part number and serial number for component and filed.

### Discrepancy Feedback Flow

A. PIRS returned to the Diproom due to traceability inaccuracies.

**CHART VI**  
**QUALITY DOCUMENTATION CENTER,**  
**ADP (PRIOR TO DD250 d) &**  
**CENTRAL CEI FILE**



**Shop Orders from Machine Shop**

1. Shop Order received from Machine Shop and Model Shop.
2. Material trace data is recorded on file card.
3. Shop Order is filed in numerical order.
4. Folder made by serial number/lot number and filed by part number for component.

**Discrepancy Feedback Flow**

- A. Shop Order returned to Machine Shop due to traceability inaccuracies.

**Fabrication Route Sheets from Production and Model Shop**

1. FIRS received from Model Shop, Hardgoods Assembly and Production Floor.
2. Parts accept/traceability tickets are verified as being accurate against parts and materials check list.
3. Materials are recorded on file card.
4. File folder made by part number, serial number for completed sub-assemblies.

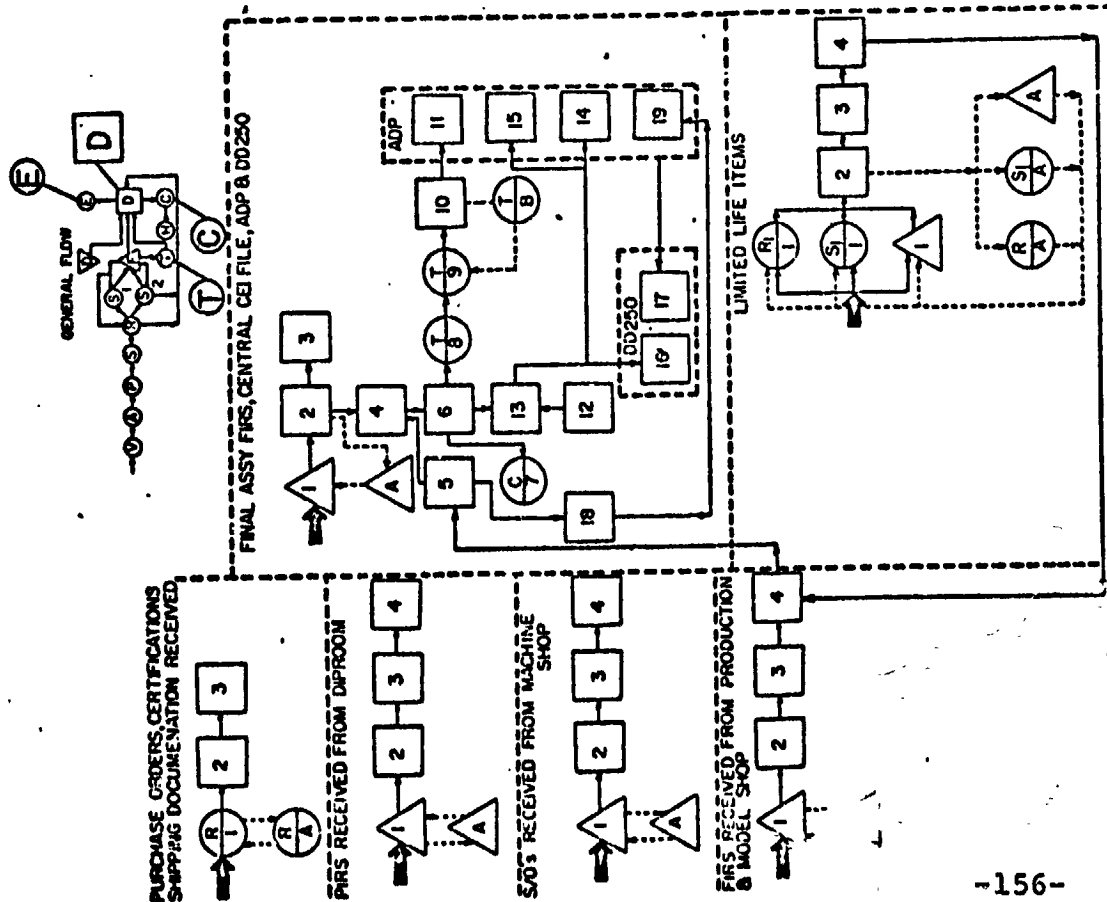
**Discrepancy Feedback Flow**

- A. FIRS returned to either Model Shop, Hardgoods Assembly or Production Floor when traceability inaccuracies occur.

**Final Assembly FIRS, Central CEI File, ADP and DD250**

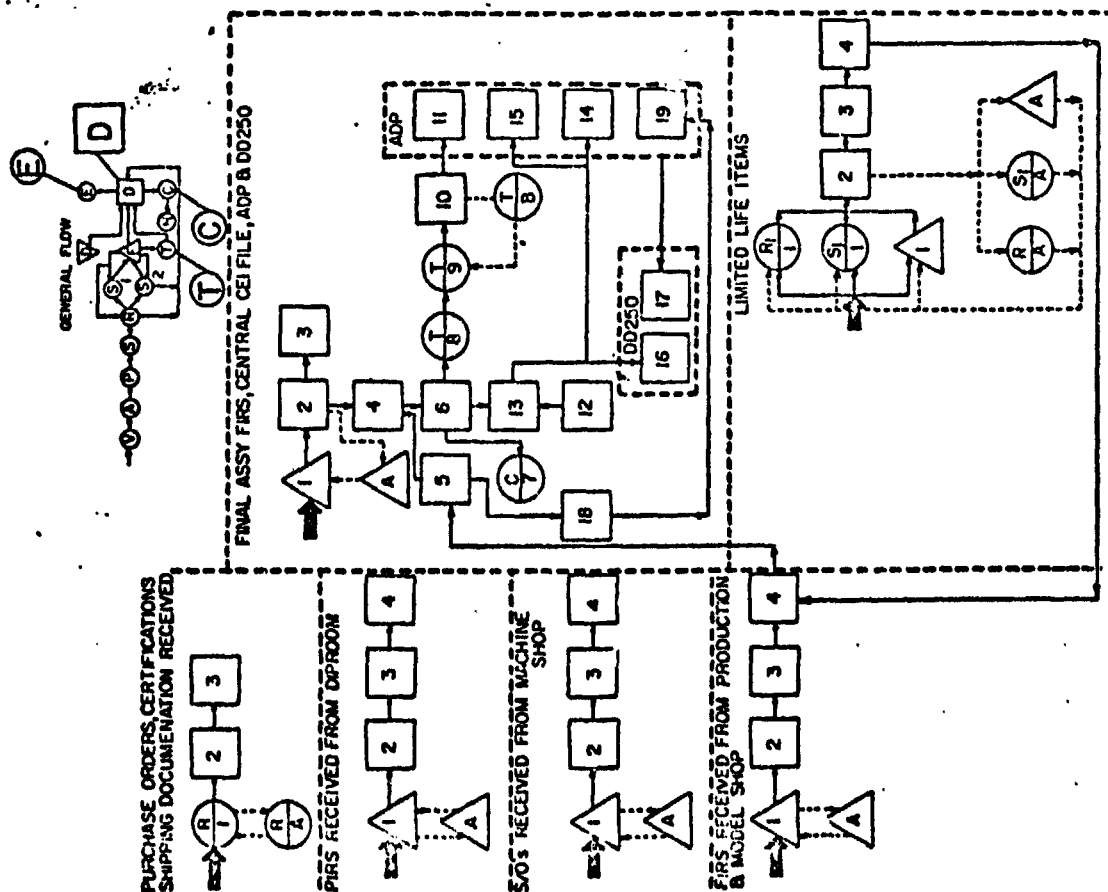
1. Final assembly FIRS are received from Production Floor.
2. Sub-assembly accept/traceability tickets and materials list is verified as accurate against final FIRS.
3. Material trace recorded on file card.

# CHART VI QUALITY DOCUMENTATION CENTER, ADP (PRIOR TO DD250 d) & CENTAL CEI FILE



4. File folder made by part number, dash number and serial number for CEI.
5. All fabricated sub-assembly files are transferred to CEI file.
6. All trace data is reviewed and accepted by Quality and NASA representative.
7. All trace data that is not required for ADP is stored in central CEI file.
8. CEI is sent to clean, for PDA after acceptance of documentation review.
9. PDA is performed and PDA report is forwarded to Quality Documentation Center.
10. All testing and verification data is verified as accurate.
11. Verified PDA report as put in ADP package after NASA representative acceptance.
12. Authorized Components List (ACL) is issued by Configuration Management Office.
13. ACL is verified against as-built configuration.
14. Verified ACL is put in the ADP package with NASA representative acceptance.
15. Differences between the as-authorized versus as-built configuration are listed in Open Engineering Section of ADP.
16. Differences between authorized and as-built configuration are listed on the DD250 (without waiver).
17. DD250 is reviewed by NASA representative.
18. Limited life data is gathered from each sub-assembly where applicable.
19. Expiration dates are recorded in applicable section of ADP.

# **CHART VI** **QUALITY DOCUMENTATION CENTER,** **ADP (PRIOR TO DD250 d) &** **CENTRAL CEI FILE**



## Discrepancy Feedback Flow

- A. Final assembly FRS returned to final assembly due to traceability inaccuracies.
- B. PDA report returned to clean room due to traceability inaccuracies.

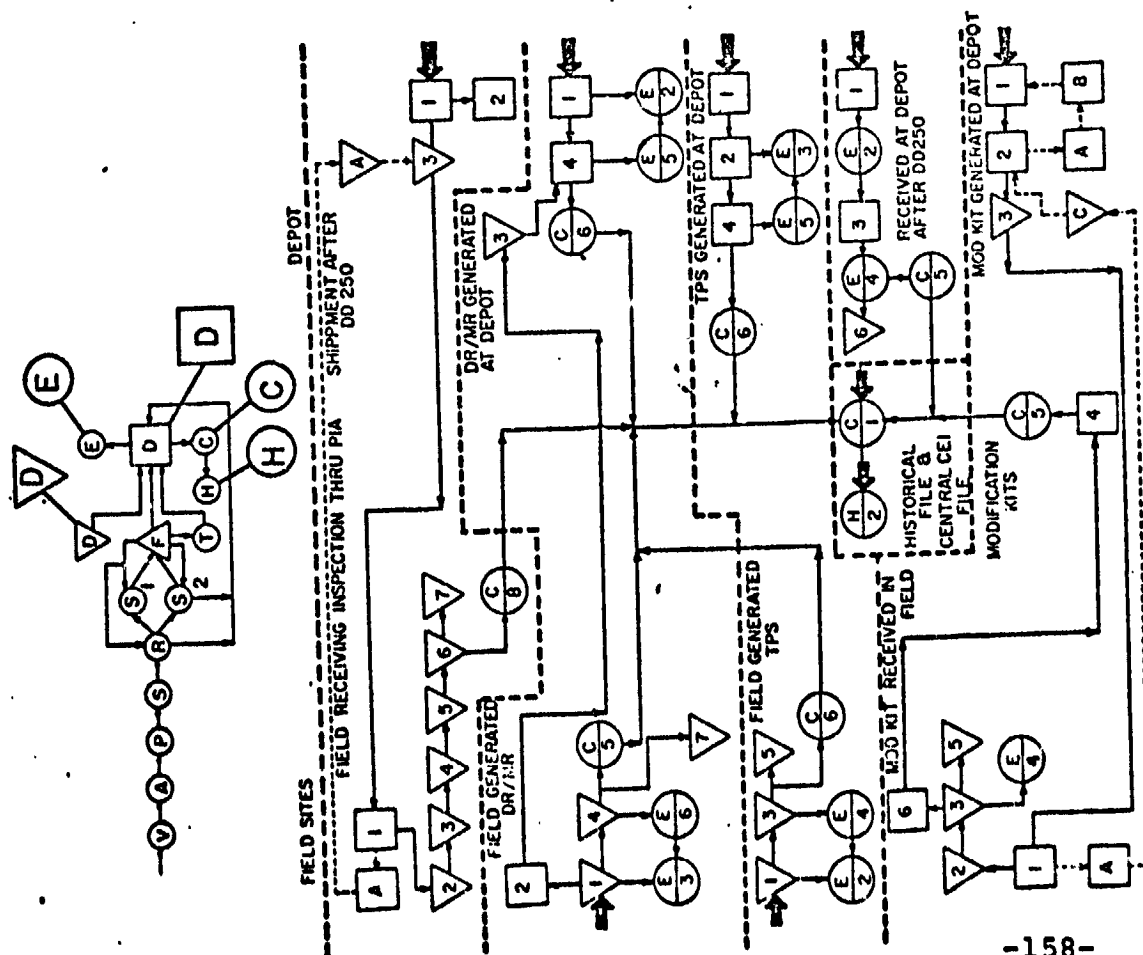
## Limited Life Items

1. Parts/materials having limited life characteristics are traced from Receiving Inspection through to ADP.
2. Limited life items are recorded on file card from Purchase Order.
3. Trace data is transferred from materials through component level to sub-assembly level.
4. Limited life data is recorded on every sub-assembly completed, including expiration date.

## Discrepancy Feedback Flow

- A. All areas are made aware of any materials, components, or subassemblies out of shelf life or too old to meet specifications for life expectancy anywhere in Production cycle.

**CHART VII**  
**QUALITY DOCUMENTATION CENTER**  
**(SUBSEQUENT TO DD 250)**



**CHART VII**

**QUALITY DOCUMENTATION CENTERS (DEPOT AND FIELD), CENTRAL AND HISTORICAL DATA CENTERS (SUBSEQUENT TO DD 250)**

**Shipment After DD250**

1. CEI is shipped at depot with ADP package as part of CEI.
2. CEI is shipped in-house.
3. CEI shipped to field site.

**Discrepancy Feedback Flow**

- A. Depot Documentation Center receives field request for additional trace data and sends required information to field when traceability inaccuracies are reported.

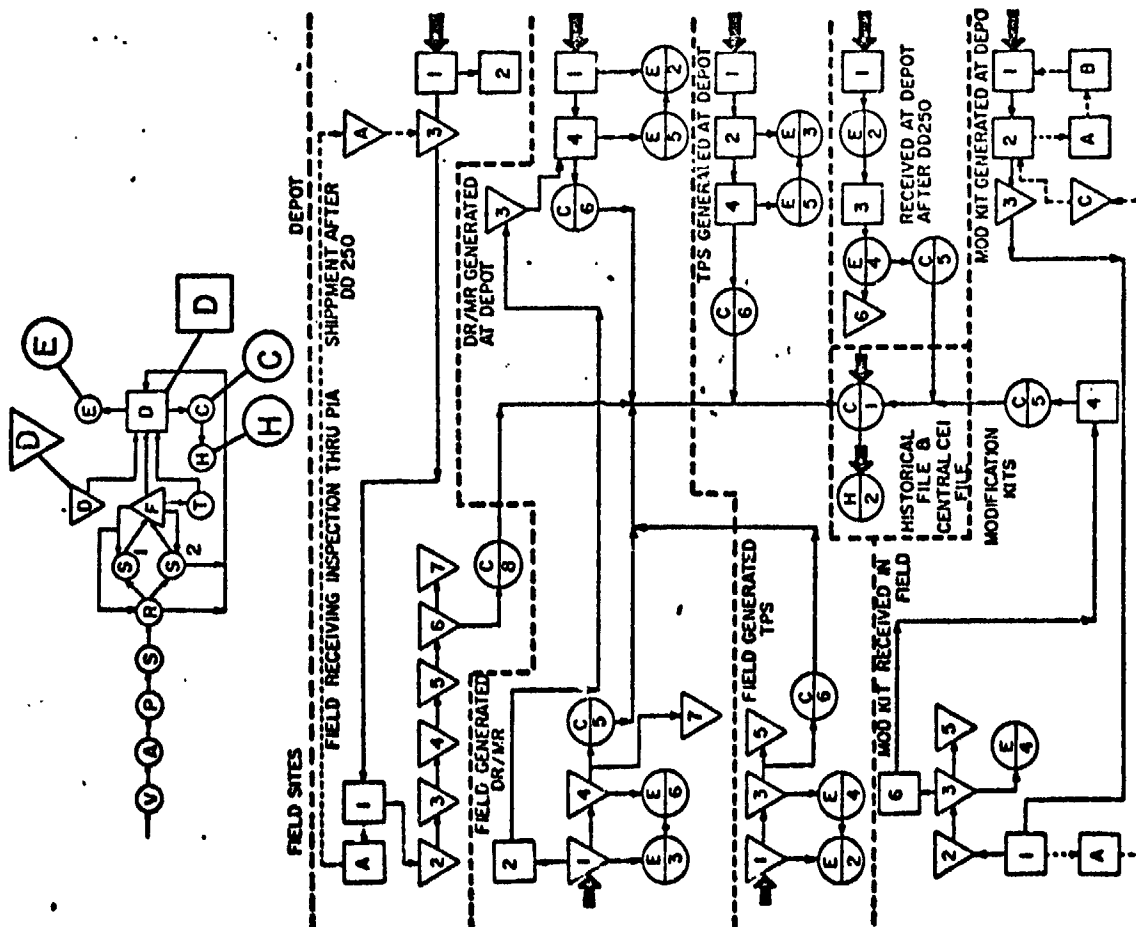
**Field Quality Documentation Receiving CEI Through PIA**

1. ADP received in Field Quality Documentation Center.
2. ADP and CEI accepted at field site after Receiving Inspection.
3. Final documentation review by Quality/CMO depot prior to PIA.
4. All (ECO) Engineering Change Orders must be incorporated or waived and all (DR/MR's) Discrepancy Reports/Material Review Boards closed before PIA.
5. PIA performed per PIA document.
6. PIA report reviewed and accepted at Quality Documentation Center.
7. PIA master filed at field site Quality Documentation Center.
8. Copy of PIA report sent to depot for filing in CEI master file.

**Discrepancy Feedback Flow**

- A. Depot Quality Documentation Center is informed by Field Quality Documentation Center if traceability information has inaccuracies.

# CHART VII QUALITY DOCUMENTATION CENTER (SUBSEQUENT TO DD250)



## TPS Generated at Field Site

1. TPS generated at field site.
2. TPS number recorded in log of ADP.
3. After close-out of ADP
4. TPS number in log of ADP is closed-out with accept stamp.
5. Original TPS is filed at Field Site.
6. Copy of TPS is sent to central CEI file.

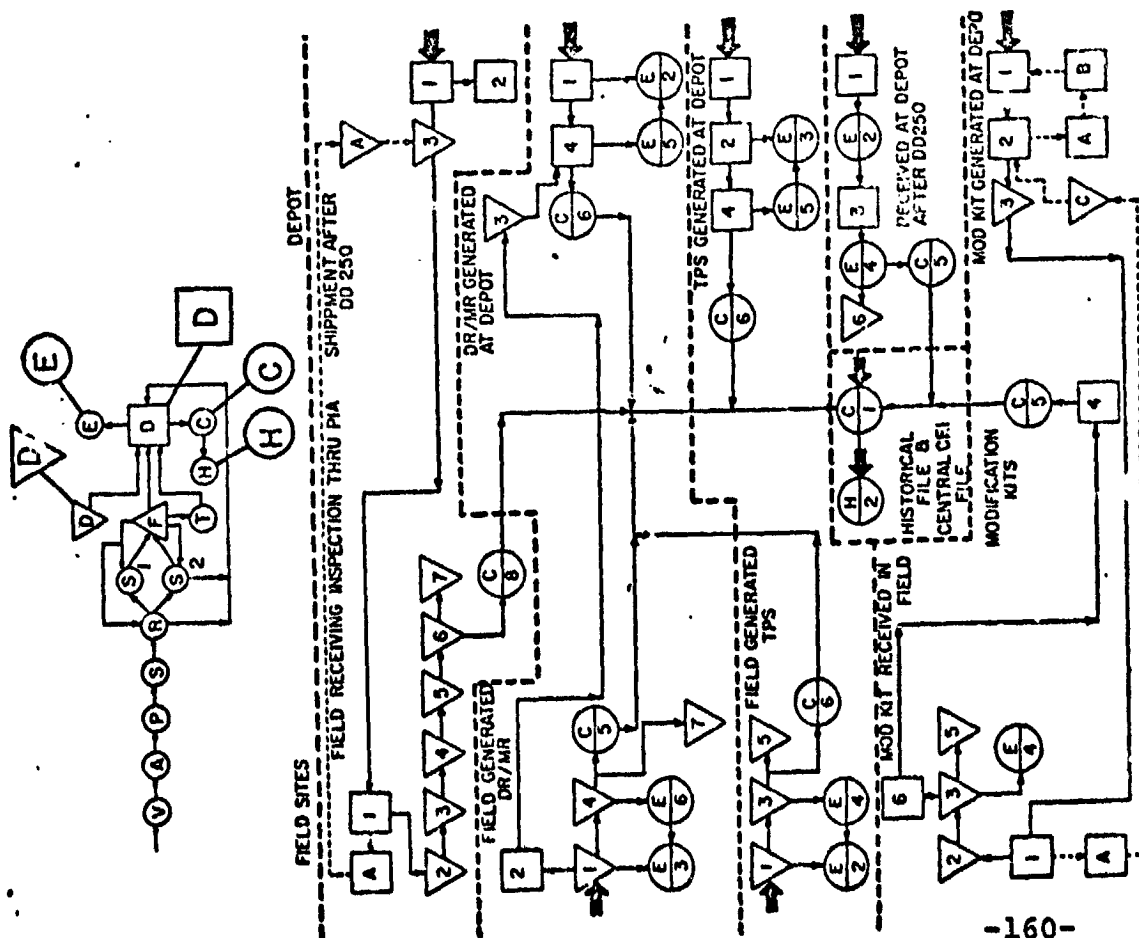
## Depot Receiving of CEI After DD250

1. CEI received at depot.
2. ADP reviewed as part of Receiving by Quality Documentation Center.
3. Work required is completed.
4. ADP reviewed by Quality Documentation Center prior to return to Field Site.
5. All in-house documentation used to accomplish task is filed in central CEI file.
6. CEI and ADP are returned to Field Site.

## Modification Kits Generated at Depot

1. TPS and modification kit generated by Program Office.
2. Quality Documentation Center reviews TPS and mod kit.
3. Returns signed TPS and Mod Kit to Program Office for shipment to Field Site.
4. Program Office receives completed Mod Kit and TPS and forwards copies to Quality Documentation Center.
5. Quality Documentation Center files copies of TPS and Mod Kit in central CEI file.

**CHART VII**  
**QUALITY DOCUMENTATION CENTER**  
**(SUBSEQUENT TO DD 250)**



**DR/MR Generated at Field Site**

1. (DR/MRR) generated against CEI.
2. DR/MRR shipped open to depot with CEI and ADP.
3. DR/MRR number recorded in log of ADP.
4. After close-out DR/MRR.
5. Copy sent to depot Quality Documentation Center for filing in CEI Central File.
6. Close-out with acceptance stamp on DR/MRR log of ADP.
7. Original filed at Field Site Quality Documentation Center.

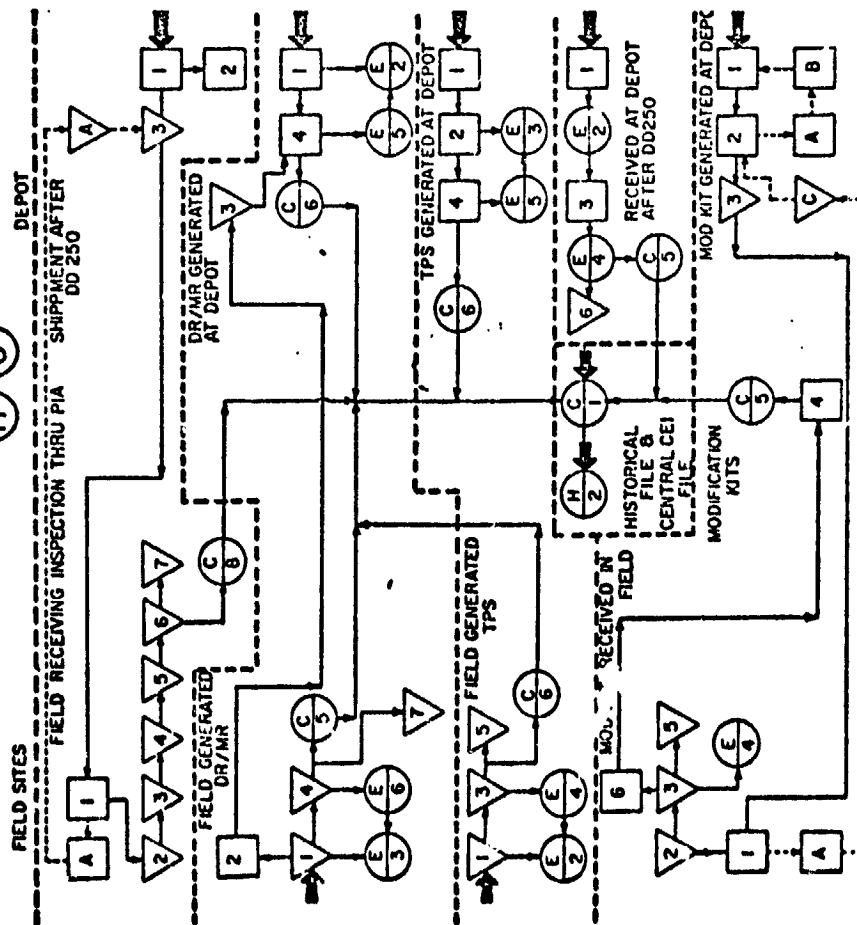
**DR/MRR Generated at Depot**

1. (DR/MRR) generated against CEI at Quality Documentation Center assigns central number.
2. DR number is recorded in DR/MRR log of ADP.
3. Open DR/MRR received from Field.
4. After close-out of DR/MRR
5. DR/MRR number in log of ADP is cleared.
6. Close-out DR/MRR is put in Central CEI file.

**TPS Generated at Depot**

1. TPS generated at depot by Program Office.
2. TPS to QC Documentation Center for review of configuration and traceability data.
3. TPS number recorded in TPS log of ADP and Form 772.
4. After TPS is completed
5. ADP TPS log is closed-out with accept stamp.
6. Copy of TPS filed in central CEI file.





- A. Quality Documentation Center returns unsigned TPS to Program Office due to configuration and trace data inaccuracies.
- B. Program corrects inaccuracies and forwards TPS and Mod Kit back to Quality Documentation Center for approval.
- C. Quality Documentation Center is informed that inaccuracies are present in Mod Kit and notifies depot corrections are required.

1. Field Site receives TPS and Mod Kit.
2. TPS and Mod Kit reviewed and accepted in Field Quality Documentation Center.
3. Mod Kit incorporated into CEI.
4. TPS logged in ADP and authorized components list updated when required.
5. Original Mod Kit and TPS filed at Field Site.
5. Copy of Mod Kit and TPS forwarded to central CEI file.

11. Depot Quality Documentation Center is informed if there are any inaccuracies in TPS or Mod Kit.

1. All data pertaining to CEI that is not part of ADP is stored in active central data file for time duration that CEI remains active (Class I or II status).
2. All data pertaining to CEI is stored in the inactive Historical File, after down grade to Class III destructive testing or following expenditure, for the period of time specified by contract.

### 5.3 TITLE:

Product Assurance Organization and Manpower Summary.

### OBJECTIVE:

Evaluate the management systems utilized for the control of Quality, Reliability and Safety during the Apollo, Skylab and ASTP suit programs. Using guidelines recommended in paragraphs 5.1 and 5.2, determine projected manpower savings.

### APPROACH:

The Product Assurance organization and operating procedures used in support of the Apollo, Skylab and ASTP suit programs were used as a comparative baseline. Guidelines discussed were used to project recommended manpower to support future suit programs.

### GROUND RULES USED FOR STUDY:

1. The Product Assurance organization for the period 1970 through 1973 was used as the study baseline. Primary emphasis was on manpower reduction.
2. The proposed Product Assurance organization was manloaded to support the program schedule shown in section 3.4 (see Figure 5.3).
3. Compliance with NASA document NHB 5300.4 was assumed to be minimum assurance requirements for future programs.

### DISCUSSION:

During the period utilized for the study, 1970 through 1973, the various assurance functions, Quality, Reliability, Safety were continually being subjected to organizational changes in order to most effectively optimize manpower utilization. As a result, ILC had formulated the Product Assurance approach of combining the overlapping or redundant functions of Quality, Reliability and Safety. This general philosophy is reflected in the proposed manpower requirements for future suit programs without attempting an in-depth evaluation of all Assurance disciplines.

The specific studies (Paragraphs 5.1 and 5.2) presented in this report were those areas which displayed the most significant cost savings potential. Flow diagrams were constructed of the past and the proposed procedures and the resulting manpower deltas. The manloading of the 1970 to 1973 organization was based on an average 1/5 production rate. In order to properly compare these organizations, the production rate was factored to reflect the estimated levels of manpower required for a 1/20 production rate. Comparison of these two programs revealed a total manpower savings of 436 man months.

QUALITY ASSURANCE A7LB ORGANIZATION

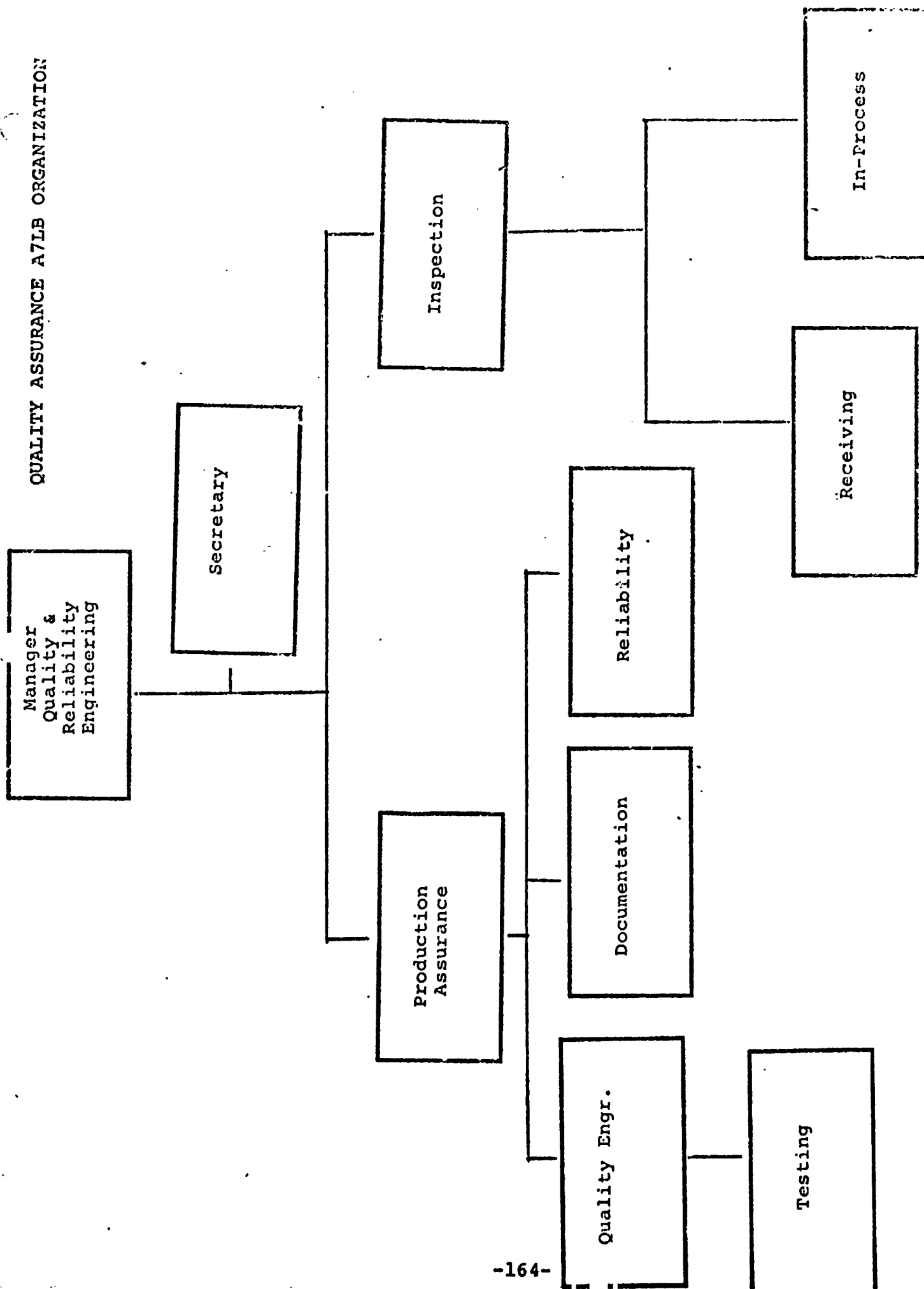
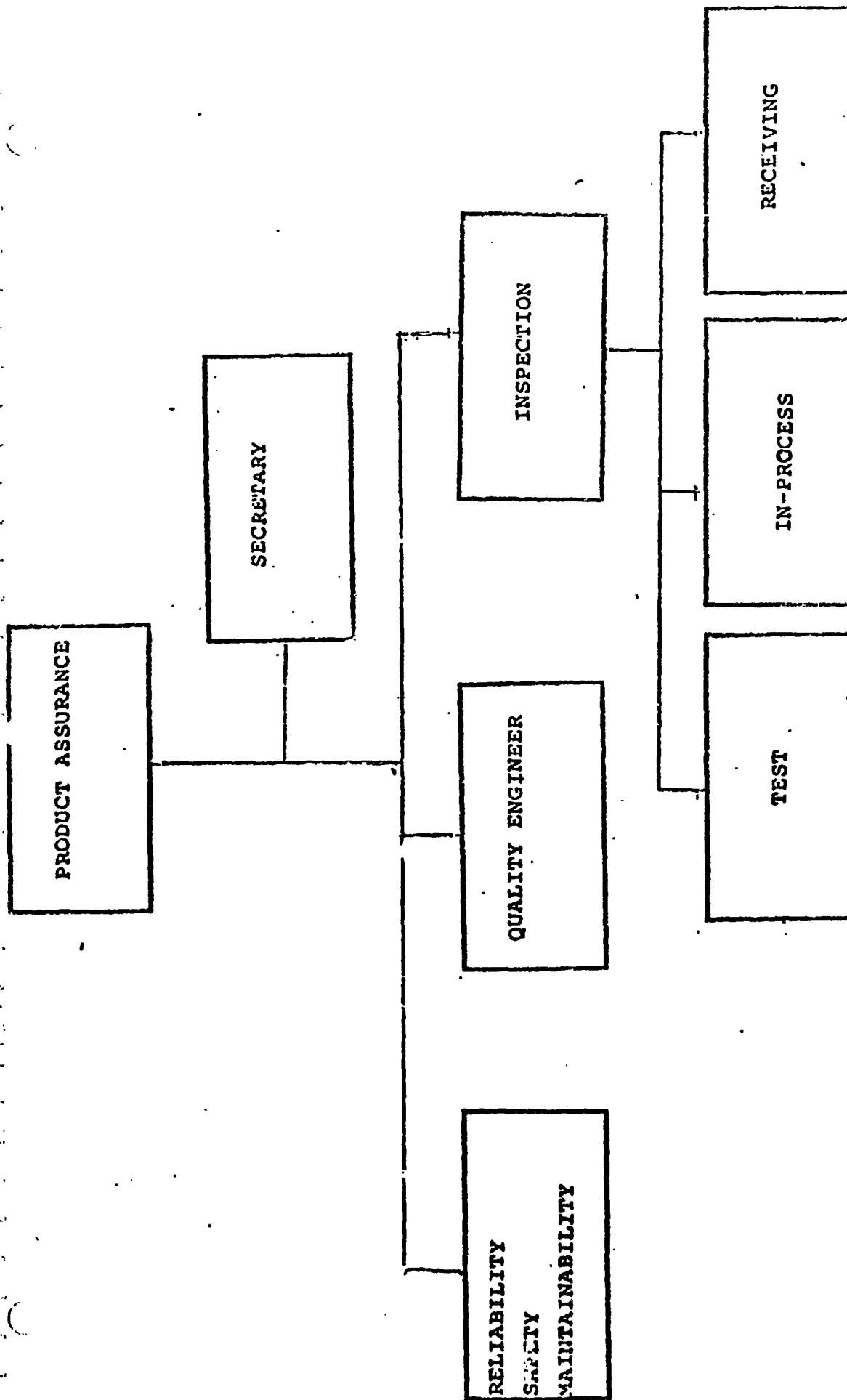




FIGURE 5.1



PRODUCT ASSURANCE ORG.  
(FUTURE PROGRAMS)

FIGURE 5.2


 AZLB PROGRAM  
 FUTURE SUIT PROGRAM

DEVELOP. 

DVT 

FAB QUAL 

QUAL 

PRODUCT. 

APOLLO/SL/ASTP		1970				1971				1972				1973			
YEAR	QUARTER																
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114

FUTURE PROGRAM		1ST				2ND				3RD				4TH			
YEAR	QUARTER																
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114

PROT ASSURANCE MANNING SUMMARY  
 REDUCTION 436 MM

FIGURE 5.5.3

## 6.0 TITLE:

### Organization and Cost Summary

#### OBJECTIVE:

Evaluate the entire program management, engineering and quality organization which existed during the Apollo, Skylab (ASTP) and ASTP suit programs. Determine the overall manpower savings resulting from the implementation of all the guidelines recommended for future suit programs.

#### APPROACH:

The ILC program management, engineering and quality organizations which supported the Apollo, Skylab (ASTP) and ASTP programs were used as a comparative baseline. The guidelines identified in Sections III, IV and V were used to formulate the recommended manpower required to support a future suit program. The resulting summary of manpower savings was then determined by a comparison of these program management organizations.

#### DISCUSSION:

As a result of this study, the following major guidelines were recommended for use on future suit programs:

1. Place emphasis on qualification of subassemblies rather than the entire spacesuit assembly.
2. FACI the first production item rather than the qualification item.
3. Qualify to the CEI worst case mission requirements the first time. *as determined by a comparison of the first time cost of the first time item to the cost of the first time item plus the cost of the first time item plus the cost of the first time item*
4. Reduce the drawing requirements by using *detail of* manufacturing instructions for configuration control.
5. Reduce 100% in-process inspection and *by appropriate* replace it with component and subassembly acceptance testing. *Component of subassembly testing to be required upon a 100% inspection*
6. Allocate sufficient time early in the program to develop efficient systems and procedures.
7. Perform <sup>2nd</sup> astronaut fit check at the user's site, *if any*.
8. Streamline data reporting requirements and centralize the data collection system.

9. Consolidate program management control functions.

The manpower level required to support a future program utilizing the recommended guidelines was then compared to the level of manpower required at ILC to support the Apollo, Skylab (A7LE) and ASTP suit programs during the period 1970 through 1973.

The manloading of the 1970 through 1973 organization was based on an average 1/5 production rate. In order to compare these organizations, the production rate was factored to reflect the estimated levels of manpower required for a 1/20 production rate. Comparison of these two programs revealed a total manpower savings of 1565 man months during a four year period if the recommended guidelines are followed. Figure 6.1 illustrates the recommended suit program manloading.



▬ A7LB PROGRAM

▬ FUTURE SUIT PROGRAM

DEVELOP. ▬

QVT ▬

FAB QUAL  
UNIT ▬

QUAL ▬

PRODUCT. ▬

APOLLO/SI/ASTP

YEAR	1970				1971				1972				1973			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
LEVEL PROPOSED FOR 1/29	414	424	414	403	381	397	383	345	313	300	287	266	224	221		4
FUTURE PROGRAM																202

YEAR	1ST				2ND				3RD				4TH			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
PROPOSED LEVEL	222	332	336	324	298	278	229	184	176	176	176	176	155	105	100	55
NET REDUCT.	92	92	78	69	89	119	154	161	137	124	111	90	69	69	64	47

PROGRAM ORGANIZATION  
REDUCTION 1565 M/M

FIGURE 6.1

APPENDIX A

-A7LB - INDENTURED PARTS LIST

REPRODUCTION OF THE ORIGINAL DATA		
A7LB-100006	Torso Limb Suit Assembly, Integrated	J
A7LB-100007	Torso Limb Suit Assembly, EV	J
A7LB-109023	Knob & Shaft Assembly, Diverter Valve	D
A7LB-109025	Mounting Plate, Diverter Valve	D
A7LB-109017	Mounting Plate, Gas Connector	D
A6L-104025	Gage Pressure Dial Indicating	D
A6L-104035	Mount, Gage	D
A6L-104034	Ring, Back	D
A7LB-109029	Wrist Disconnect, Suit Side, Left	D
A7LB-109029	Wrist Disconnect, Suit Side, Right	D
A7LB-109010	Neck Ring, Suit Side	D
A7LB-109013	Mounting, Ring Neck	D
A7LB-101189	Upper PLSS Attachment Assembly	C
A7LB-101190	Bracket, Attachment, PLSS	C
A7LB-101191	Bar, Attachment, Connector	C
A7LB-104084	Arm Bear Assembly	D
A7L-104046	Seal, Wiper	C
A7L-104060	Ball, Port	C
A7LB-104092	Race, Inner	E
A7LB-104130	Outer, Race Assembly, Arm Bearing	D
A7L-104076	Spacer	B
	Four - ST Drawings	B
	One - MS Drawing	A
A7LB-104135	Ring Retaining, Convolute Arm Bearing	D
A7LB-104136	Tab, Locking Arm Bearing	C
<del>A7LB-101203</del>	<del>Strip Assembly, Attach. #12</del>	E
<del>A7LB-1S1302</del>	<del>Strip, Base #12-(Pattern)</del>	C
	Two - ST Drawings	B
<del>A7LB-101204</del>	<del>Fast Strip Assembly, Torso</del>	D
<del>A7LB-121312</del>	<del>Fastener Tape, Pile-Entrance-Zipper</del>	E
	Four - ST Drawings	B
A6L-101017	Flange, Outer, Electrical	C
A6L-101016	Flange, Inner, Electrical	C
<del>A7LB-101135</del>	<del>Thigh Cable Guide, Patch Assembly</del>	C
<del>A6L-104003</del>	<del>Guide, Cord</del>	B
	Two - ST Drawings	B
<del>A6L-104018</del>	<del>Cover Strip Assembly, Wrist</del>	B
<del>A6L-104018</del>	<del>Tape &amp; Webbing Reinforcement</del>	B
	One - ST Drawing	B
<del>A6L-101044</del>	<del>Washer, Grommet</del>	B
A7LB-101155	Tube, Waist Cable Guide	C
A7LB-109018	Housing Assembly, Inner Gas Connector	D
A7LB-109020	Spring Gas Connector	B
A7LB-109038	Ring Clamping & Multi H <sub>2</sub> O	C
<del>A7L-109000</del>	<del>Screw, Modified</del>	D
<del>A7LB-101209</del>	<del>Strip Assembly, Attach. #7</del>	C
<del>A7LB-1S1285</del>	<del>Strip, Base #7-(Pattern)</del>	C
	Two - ST Drawings	B

~~A7LB-101209~~ Strip Assembly, Attach. #8  
~~A7LB-1S1286~~ Strip, Base #8 (Pattern)  
 Two - ST Drawings  
~~A7LB-101209~~ Strip Assembly, Attach. #9  
~~A7LB-1S1287~~ Strip, Base #9 (Pattern)  
 Two - ST Drawings  
~~A7LB-101209~~ Strip Assembly, Attach. #10  
~~A7LB-1S1288~~ Strip, Base #10 (Pattern)  
 Two - ST Drawings  
~~A7LB-101209~~ Strip Assembly, Attach. #11  
~~A7LB-1S1289~~ Strip, Base #11 (Pattern)  
 Two - ST Drawings  
~~A7LB-108026~~ Arm Vent Duct Assembly, Left  
~~A6L-1S8021~~ Pattern  
~~A6L-1S8021~~ Pattern  
~~A6L-1S8009~~ Pattern  
~~A6L-1S8008~~ Pattern  
~~A6L-1S8008~~ Pattern  
~~A7L-1S8022~~ Pattern  
~~A7LB-108024~~ Space Assembly, Vent, Arm  
~~A7LB-1S8022~~ Pattern  
 A7LB-109031 Connector, Vent Duct  
~~A7LB-1S8023~~ Pattern  
~~A7LB-1S8023~~ Pattern  
 Four - ST Drawings  
~~A7LB-108027~~ Arm Vent Duct Assembly, Right  
~~A6L-1S8021~~ Pattern  
~~A6L-1S8021~~ Pattern  
~~A6L-1S8009~~ Pattern  
~~A6L-1S8008~~ Pattern  
~~A6L-1S8008~~ Pattern  
~~A7LB-1S8019~~ Pattern  
 A7LB-109031 Connector, Vent Duct  
~~A7LB-108024~~ Spacer Assembly, Vent, Arm  
 Four - ST Drawings  
 A6L-105010 Sleeve, Crotch, Double End  
~~A7L-104083~~ Cover Strip Assembly, Upper Arm  
~~A7L-104083~~ Tape & Webbing Reinforcement  
 One - ST Drawing  
~~A6L-101074~~ Sleeve, 3/32" Dia. Cable Modified  
~~A7LB-101204~~ Fast. Strip Assy., Terso  
~~A7LB-1Z1312~~ Fastener Tape (Pattern)  
 Four - ST Drawings  
 A6L-104033 Nut, Gage  
~~A7LB-100011~~ Label CEI Ident. Assy. Integ. TL5A  
 Five - ST Drawings  
 A6L-101024 Swivel, Label Ends, Shld. Retaining

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A7LB-101226	Cable Guide Assembly, Rear	C
A6L-101045	Plate Mounting	B
A7LB-101225	Tube, Flared Cable Guide	C
	Two - ST Drawings	B
<del>A7LB-101216</del>	<del>Swage Fitting, Shoulder</del>	<del>C</del>
A7L-101035	Plug, Water Connector	D
A7LB-109016	Housing Assembly, Outer Gas Connector, Inlet	D
A7LB-109016	Housing Assembly, Outer Gas Connector, Outlet	D
A7L-101116	Base Plate, Shoulder Cable Connector	C
A7L-101117	Cover Shoulder, Cable Connector	D
A7LB-101229	Terminal, Swaging Cable	C
<del>A7LB-101235</del>	<del>Rivet, Shoulder, Restraint-Rear Neck</del>	<del>B</del>
A7LB-104095	Ring & Cable Guide Assembly, Shoulder	E
A7LB-104140	Ring & Cable Guide Sub-Assembly, Shoulder	E
A7LB-104105	Ring Form	D
A7LB-104097	Angle, Reinforcing	C
A7LB-104096	Tubing Guide, Shoulder Assembly	C
A7LB-104106	Support, Swivel	C
A7LB-104094	Washer, Thrust	C
A7LB-104102	Shaft, Pulley	C
A7LB-104103	Shaft, Swivel	C
A7LB-104094	Washer, Thrust	C
A7LB-104101	Bushing, Clevis	C
A7LB-104100	Clevis Pulley Assembly	C
<del>A7LB-104098</del>	<del>Pulley Assembly, Cable</del>	<del>C</del>
A7LB-104128	Pulley Cable	C
	Three - ST Drawings	B
	Four - ST Drawings	B
	Four - AN Drawings	A
<del>A7LB-101166</del>	<del>Pulley Assembly, Waist, LH</del>	<del>D</del>
A7LB-101197	Pulley & Bearing Assembly, Waist	D
A7LB-101164	Cover, Pulley Assembly, Waist LH	C
A7LB-101160	Clip, Pulley Assembly, Waist LH	D
A7LB-101165	Cable Guide	C
A7LB-101199	Screw, LM Restr. Attachment	B
A7LB-101157	Bracket, LN Restr. Attachment	B
A7LB-101167	Weldment, Pulley Assy., Waist LH	D
A7LB-101197	Pulley & Bearing Assy., Waist	D
	Two - ST Drawings	B
	One - MS Drawing	A
<del>A7LB-101166</del>	<del>Pulley Assembly, Waist, RH</del>	<del>D</del>
A7LB-101197	Pulley & Bearing Assembly, Waist	C
A7LB-101165	Cable Guide	C
A7LB-101160	Clip, Pulley Assy., Waist RH	C
A7LB-101164	Cover Pulley Assy., Waist RH	D
A7LB-101199	Screw, LM Restr. Attachment	C
A7LB-101157	Bracket, LM Restr. Attachment	C

A7LB-101167	Weldment, Pulley Assembly, Waist RH	D
	Two - ST Drawings	B
	One - MS Drawing	A
A7LB-108038	Sleeve Plenum , Mtg. Diverter Valve	C
A7LB-108038	Sleeve, Plenum, Mtg. Diverter Valve	C
A7LB-101122	Bracket Assembly, Neck Turn Around RH	C
A7LB-104106	Ferrule, Guide	B
A7LB-101123	Bracket, Right Hand	D
A7LB-101124	Tubing	C
	Two - ST Drawings	B
A7LB-101122	Bracket Assembly, Neck Turn Around LH	C
A7LB-104106	Ferrule, Guide	B
A7LB-101123	Bracket, Left Hand	D
A7LB-101124	Tubing	C
	Two - ST Drawings	B
<del>A7LB-104153</del>	<del>Cover Assembly, Shoulder Left</del>	D
<del>A7LB-1S4071</del>	<del>Pattern</del>	E
<del>A6L-109001</del>	<del>Loop Tape, Modified</del>	B
<del>A7LB-1S4070</del>	<del>Pattern</del>	E
	Two - ST Drawings	D
<del>A7LB-104153</del>	<del>Cover Assembly, Shoulder Right</del>	D
<del>A7LB-1S4071</del>	<del>Pattern</del>	E
<del>A6L-109001</del>	<del>Loop Tape, Modified</del>	B
<del>A7LB-1S4070</del>	<del>Pattern</del>	B
	Two - ST Drawings	C
<del>A7LB-100018</del>	<del>Label Assembly, Warning</del>	C
<del>A7LB-1S1404</del>	<del>Pattern</del>	C
	Four - ST Drawings	B
A7LB-101182	Lock Assembly, Restraint Zipper	E
A7LB-101183	Housing, Lock, Restr. Zipper	E
<del>A7LB-101193</del>	<del>Tab Assembly, Lock-Lock</del>	C
A7LB-101184	Tab, Lock-Lock	C
A7LB-101185	Pin, Lock-Lock	C
A7LB-101214	Bushing, Centering	C
	One - ST Drawing	B
A7LB-101186	Strike, Zipper Lock	C
A7LB-101187	Plate, Spring Retainer	C
A7LB-101253	Pin, Slider, Mounting	C
A7LB-101256	Housing Lock, Restraint Zipper	E
	Three - ST Drawings	B
	Two - MS Drawings	A
A7LB-108018	Inlet & Torso Plenum Assembly	D
A7LB-108020	Plenum Gas Connector Inlet	D
A7LB-108021	Plenum Torso Duct	C
<del>A7LB-1S8026</del>	<del>Pattern</del>	C
<del>A7LB-1S8025</del>	<del>Pattern</del>	D
A7LB-108022	Spacer Assembly, Torso Vent	D

<del>A7LB-1S8014</del>	<del>Pattern</del>	C
<del>A7LB-1S8013</del>	<del>Pattern</del>	C
	Three - ST Drawings	E
<del>A7LB-1S8027</del>	<del>Pattern</del>	C
<del>A7LB-1S8028</del>	<del>Pattern</del>	C
<del>A7LB-1S8033</del>	<del>Pattern</del>	C
<del>A7LB-1S8033</del>	<del>Pattern</del>	C
A7LB-109019	Cage, Vent Duct, Gas Connector	D
A7LB-109026	Cage, Vent Duct, Diverter Valve	D
A7LB-109048	Screen, Diverter Valve	C
A7LB-108037	Exhaust Assembly, Plenum Assembly	D
A7LB-108019	Plenum, Exhaust, Gas Connector	D
<del>A7LB-1S8025</del>	<del>Pattern</del>	C
A7LB-108032	Spacer Assembly, 6 Coils	D
<del>A7LB-1S8033</del>	<del>Pattern</del>	C
<del>A7LB-1S8033</del>	<del>Pattern</del>	C
A7LB-109019	Cage Vent Duct, Gas Connector	D
	Three - ST Drawings	B
A7LB-104086	Arm Assembly, Upper Left	E
<del>A7LB-104152</del>	<del>Convolute Assembly, Shoulder, Left</del>	D
A7LB-104151	Convolute, Shoulder, Left	D
<del>A7LB-1S4068</del>	<del>Pattern</del>	C
<del>A7LB-1S4067</del>	<del>Pattern</del>	C
	One - ST Drawing	B
<del>A7LB-104115</del>	<del>Restraint &amp; Bladder Assembly, Left</del>	D
<del>A7LB-104114</del>	<del>Restr. Assembly, Upper Arm Cone, Left</del>	E
<del>A7LB-1S4069</del>	<del>Pattern</del>	D
<del>A7LB-1S4053</del>	<del>Pattern</del>	C
<del>A7LB-1S4054</del>	<del>Pattern</del>	D
<del>A7LB-1S4035</del>	<del>Pattern</del>	D
	Thirteen - ST Drawings	B
<del>A7LB-104116</del>	<del>Bladder Assembly, Upper Arm Cone, Left</del>	E
<del>A7LB-1S4056</del>	<del>Pattern</del>	D
<del>A7LB-1S4057</del>	<del>Pattern</del>	C
<del>A7LB-1S4058</del>	<del>Pattern</del>	D
<del>A7LB-1S4059</del>	<del>Pattern</del>	C
<del>A7LB-101208</del>	<del>Strip Assembly Attachment</del>	E
	Six - ST Drawings	B
A6L-104003	Guide, Teflon	B
	Eight - ST Drawings	B
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	B
	Eight - ST Drawings	B
A7B-104086	Arm Assembly, Upper Right	E
<del>A7LB-104152</del>	<del>Convolute Assembly, Shoulder, Right</del>	D
A7LB-104151	Convolute, Shoulder, Right	D
<del>A7LB-1S4068</del>	<del>Pattern</del>	C
<del>A7LB-1S4067</del>	<del>Pattern</del>	C
	One - ST Drawing	B

<del>A7LB-104115</del>	<del>Restriant &amp; Bladder Assy., Right</del>	D
<del>A7LB-104114</del>	<del>Restr. Assy., Upper Arm Cone, Right</del>	E
<del>A7LB-1S4069</del>	<del>Pattern</del>	C
<del>A7LB-1S4053</del>	<del>Pattern</del>	D
<del>A7LB-1S4054</del>	<del>Pattern</del>	C
<del>A7LB-1S4035</del>	<del>Pattern</del>	D
	Thirteen - ST Drawings	P
<del>A7LB-104116</del>	<del>Bladder Assembly, Upper Arm Cone, Right</del>	E
<del>A7LB-1S4056</del>	<del>Pattern</del>	D
<del>A7LB-1S4057</del>	<del>Pattern</del>	D
<del>A7LB-1S4058</del>	<del>Pattern</del>	D
<del>A7LB-1S4059</del>	<del>Pattern</del>	C
<del>A7LB-101208</del>	<del>Strip Assembly, Attachment</del>	E
	Six - ST Drawings	B
A6L-104003	Guide, Teflon	B
	Eight - ST Drawings	B
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	B
	Eight - ST Drawings	B
<del>A7LB-108028</del>	<del>Helmet Vent Duct Assembly</del>	E
A7LB-108031	Connector, Vent Duct, Helmet	C
<del>A7LB-108025</del>	<del>Spacer, Assembly, Helmet</del>	D
<del>A7LB-1S8015</del>	<del>Pattern</del>	J
	Three - ST Drawings	B
<del>A7LB-1S8020</del>	<del>Pattern</del>	D
<del>A7LB-1S8020</del>	<del>Pattern</del>	D
	Four - ST Drawings	B
A7LB-108045	Diverter Valve & Duct Seal Assembly	D
A7LB-109037	Receptacle Assembly, Multi H <sub>2</sub> O Conn.	D
<del>A7LB-108029</del>	<del>Leg Vent Duct Assembly</del>	E
<del>A7LB-1S8021</del>	<del>Pattern</del>	E
<del>A7LB-1S8021</del>	<del>Pattern</del>	E
<del>A7LB-1S8024</del>	<del>Pattern</del>	D
<del>A7LB-1S8024</del>	<del>Pattern</del>	D
<del>A6L-1S8016</del>	<del>Pattern</del>	J
<del>A7LB-108023</del>	<del>Spacer Assembly, Leg</del>	E
<del>A7LB-1S8016</del>	<del>Cover, Vent Spacer, Leg</del>	J
	Three - ST Drawings	B
	Two - ST Drawings	B
A7LB-107028	Liner Assembly - TL5A	J
<del>A7LB-107036</del>	<del>Reinforcement Assembly, Lock Lock</del>	
	Cut Out	C
<del>A7LB-1S7102</del>	<del>Pattern</del>	C
	One ST Drawing	E
<del>A7LB-127053</del>	<del>Pattern</del>	E
<del>A7LB-127053</del>	<del>Pattern</del>	E
<del>A7LB-127054</del>	<del>Pattern</del>	E
<del>A7LB-127054</del>	<del>Pattern</del>	E
<del>A7LB-107029</del>	<del>Fastener Strip, Upper Wrist</del>	E
<del>A7LB-107029</del>	<del>Fastener Strip, Torso</del>	E



~~A7LB-1G7029~~ ----- Fastener Strip, Upper Wrist  
~~A7LB-1G7029~~ ----- Fastener Strip, Lower Wrist  
~~A7LB-1G7030~~ ----- Pad Assembly, Upper Arm Cone  
~~A7LB-1S7076~~ ----- Pattern  
~~A7LB-1S7045~~ ----- Pattern  
One - ST Drawing  
~~A7LB-1Z7055~~ ----- Pattern  
~~A7LB-1Z7056~~ ----- Pattern  
~~A7LB-1Z7056~~ ----- Pattern  
~~A7LB-1Z7048~~ ----- Pattern  
~~A7LB-1G7050~~ ----- Pattern  
~~A7LB-1C7050~~ ----- Pattern  
~~A7LB-1S7065~~ ----- Pattern  
~~A7LB-1S7066~~ ----- Pattern  
~~A7LB-1S7067~~ ----- Pattern  
~~A7LB-1S7068~~ ----- Pattern  
~~A7LB-1C7052~~ ----- Pattern  
~~A7LB-1S7073~~ ----- Pattern  
~~A7LB-1G7031~~ ----- Pad Assembly, Shoulder  
~~A7LB-1S7012~~ ----- Pattern  
~~A7LB-1S7069~~ ----- Pattern  
One - ST Drawing  
~~A7LB 1G7029~~ ----- Fastener Strip, Lower Wrist  
~~A7LB-1G7029~~ ----- Fastener Strip, Torso  
~~A7LB-1S7063~~ ----- Pattern  
~~A7LB-1S7062~~ ----- Pattern  
~~A7LB-1Z7076~~ ----- Pattern  
~~A7LB-1G7032~~ ----- Comfort Pad Assembly, Knee  
~~A7LB-1S7031~~ ----- Pattern  
~~A7LB-1S7031~~ ----- Pattern  
One - ST Drawing  
~~A7LB-1G7032~~ ----- Comfort Pad Assembly, Underarm  
~~A7LB-1Z7080~~ ----- Pattern  
~~A7LB-1Z7083~~ ----- Pattern  
One - ST Drawing  
~~A7LB-1G7032~~ ----- Pad Assembly, Comfort, Crotch  
~~A7LB-1Z7079~~ ----- Pattern  
~~A7LB-1S7082~~ ----- Pattern  
One - ST Drawing  
~~A7LB-1Z7075~~ ----- Pattern  
~~A7LB-1Z7077~~ ----- Pattern  
~~A7LB-1Z7078~~ ----- Pattern  
~~A7LB-1G7061~~ ----- Pattern  
~~A7LB-1G7029~~ ----- Fastener Strip, Neck  
~~A7LB-1S7049~~ ----- Pattern  
~~A7LB-1S7049~~ ----- Pattern  
~~A7LB-1S7097~~ ----- Pattern

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~~A7LB-107034~~ Strap, UCTA Hose Retaining  
~~A7LB-107035~~ Chin Pad, Liner Assembly  
~~A7LB-1S7099~~ Pattern  
~~A7LB-1S7100~~ Pattern  
 One - ST Drawing  
~~A7LB-1C7052~~ Pattern  
~~A7LB-1Z7055~~ Pattern  
 Fourteen - ST Drawings  
~~A7LB-101213~~ Fastener Strip Assembly, Neck  
 Five - ST Drawings  
~~A7LB-101212~~ Guide Assembly, Crotch Cable  
~~A6L-1S1015~~ Pattern  
~~A7LB-1S1417~~ Pattern  
~~A7LB-1S1416~~ Pattern  
 Two - ST Drawings  
 A7LB-104085 Arm Assembly, Lower Left  
~~A7LB-104157~~ Convolute Assembly, Elbow  
 A7LB-104156 Convolute, Elbow  
 Six - ST Drawings  
 One - MS Drawing  
~~A7LB-104123~~ Fastener Strip, Wrist, Lwr. L  
~~A7LB-104127~~ Restr. & Bladder Assembly, Left  
~~A7LB-104125~~ Restr. Assembly, Wrist Cone, Left  
~~A7LB-1Z4062~~ Pattern  
~~A6L-109001~~ Tape, Loop, Modified  
~~A7L-1S4004~~ Pattern  
 Seven - ST Drawings  
~~A7LB-1C4124~~ Bladder Assembly, Wrist Cone, L.  
~~A7LB-1Z4060~~ Pattern  
~~A7LB-1Z4061~~ Pattern  
 Five - ST Drawings  
~~A7LB-1Z4048~~ Pattern  
 Two - ST Drawings  
 A6L-101044 Washer, Eyelet  
 Six - ST Drawings  
 Two - AN Drawings  
 A7LB-104085 Arm Assembly, Lower Right  
~~A7LB-104157~~ Convolute Assembly, Elbow  
 A7LB-104156 Convolute, Elbow  
 Six - ST Drawings  
 One - MS Drawing  
~~A7LB-104123~~ Fastener Strip, Wrist, Lwr. - R.  
~~A7LB-104127~~ Restr. & Bladder Assembly, Right  
~~A7LB-104125~~ Restr. Assembly, Wrist Cone, Right  
~~A7LB-1Z4062~~ Pattern  
~~A6L-109001~~ Tape, Loop, Modified  
~~A7L-1S4004~~ Pattern  
 Seven - ST Drawings

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<del>A7LB-104124</del>	Bladder Assembly, Wrist Conc, R	D
<del>A7LB-124060</del>	Pattern	D
<del>A7LB-124061</del>	Pattern	D
	Five - ST Drawings	B
<del>A7LB-124048</del>	Pattern	C
	Two - ST Drawings	B
A6L-101044	Washer, Eyelet	B
	Six - ST Drawings	B
	Two - AN Drawings	A
A7LB-104093	Bracket Cable Retention	C
A7LB-106061	Boot Assembly, TLSA, Left	E
<del>A7LB-106063</del>	Bladder, Liner & Vent Assembly, Boot	E
	Left	E
<del>A7LB-126117</del>	Pattern	D
<del>A7L-106618</del>	Outsole Assembly, Bladder Left	D
<del>A7L-126037</del>	Pattern	B
	Two - ST Drawings	D
<del>A7L-106019</del>	Liner & Vent Assembly, Boot	E
<del>A7LB-106074</del>	Liner Assembly, Boot Left	D
<del>A7LB-1S6127</del>	Pattern	D
<del>A7LB-126123</del>	Pattern	E
<del>A7LB-126118</del>	Pattern	D
<del>A7L-126038</del>	Pattern	B
	Three - ST Drawings	C
<del>A7L-1S6045</del>	Pattern	D
<del>A7L-106019-03</del>	Patch, Reinforcement	C
<del>A7L-1S6046</del>	Pattern	D
<del>A7L-126044</del>	Pattern	D
<del>A7L-126043</del>	Pattern	D
<del>A7L-126042</del>	Pattern	D
<del>A7L-126041</del>	Pattern	B
	Six - ST Drawings	E
<del>A7LB-106072</del>	Restraint, Heel & Sole Assembly, Boot	D
	Left	C
<del>A7LB-106071</del>	Sole Assembly, Left	C
<del>A6L-126007</del>	Pattern	B
<del>A7L-126033</del>	Pattern	D
A7L-106012	Nut, Flanged	D
<del>A7L-126031</del>	Pattern	B
<del>A7L-126032</del>	Pattern	D
	One - ST Drawing	D
<del>A7LB-106070</del>	Heel Assembly, Boot	D
<del>A7L-1S6029</del>	Pattern	C
<del>A7L-1S6075</del>	Pattern	B
	One - ST Drawing	B
A7L-106010	Screw, Heel Shank	B
A7L-106013	Screw, Arch Shank	D
<del>A7L-106016</del>	Insole Assembly, Restraint Left	D
<del>A7L-126034</del>	Pattern	B
	Two - ST Drawings	

A7L-106014	Arch/Heel Shank	
<del>A7L-1S6077</del>	<del>Pattern</del>	
<del>A7L-1S6077</del>	<del>Pattern</del>	
<del>A7L-1S6077</del>	<del>Pattern</del>	
<del>A7L-1S6078</del>	<del>Pattern</del>	
A7L-106005	Restraint Assembly, Boot, Left	
<del>A7L-1Z6001</del>	<del>Pattern</del>	
<del>A7L-1Z6002</del>	<del>Pattern</del>	
<del>A7L-1S6008</del>	<del>Pattern</del>	
<del>A7L-1S6021</del>	<del>Pattern</del>	
<del>A7L-1S6036</del>	<del>Pattern</del>	
<del>A7L-1Z6042</del>	<del>Pattern</del>	
<del>A7L-1Z6047</del>	<del>Pattern</del>	
<del>A7L-106007</del>	<del>Cable &amp; Ferrule Assembly, Boot</del>	
A6L-106007	Ferrule, Cord Guide, Small	
A7L-106007	Tube, Shrinkable	
A7L-106007	Tube, Shrinkable	
	Two - ST Drawings	
A6L-106007	Ferrule, Cord Guide, Small	
<del>A7L-1Z6025</del>	<del>Pattern</del>	
<del>A7L-1Z6024</del>	<del>Pattern</del>	
<del>A7L-1Z6022</del>	<del>Pattern</del>	
<del>A7L-1S6017</del>	<del>Pattern</del>	
	Six - ST Drawings	
	Five - ST Drawings	
	One - ST Drawing	
A7LB-106061	Boot Assembly, TL5A Right	
<del>A7LB-106063</del>	<del>Bladder Liner &amp; Vent Assembly, Boot</del>	
	Right	
<del>A7LB-1Z6117</del>	<del>Pattern</del>	
<del>A7L-106018</del>	<del>Outsole Assembly, Bladder Right</del>	
<del>A7L-1Z6037</del>	<del>Pattern</del>	
	Two - ST Drawings	
<del>A7L-106019</del>	<del>Liner &amp; Vent Assembly, Boot</del>	
<del>A7LB-106074</del>	<del>Liner Assembly, Boot Left</del>	
A7LB-1S6127	Pattern	
<del>A7LB-1Z6123</del>	<del>Pattern</del>	
<del>A7LB-1Z6118</del>	<del>Pattern</del>	
<del>A7LB-1Z6038</del>	<del>Pattern</del>	
	Three - ST Drawings	
<del>A7L-1S6045</del>	<del>Pattern</del>	
<del>A7L-106019-03</del>	<del>Pattern</del>	
<del>A7L-1S6046</del>	<del>Pattern</del>	
<del>A7L-1Z6044</del>	<del>Pattern</del>	
<del>A7L-1Z6043</del>	<del>Pattern</del>	
<del>A7L-1Z6042</del>	<del>Pattern</del>	
<del>A7L-1Z6041</del>	<del>Pattern</del>	
	Six - ST Drawings	

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<del>A7LB-106072</del>	<del>Restraint, Heel &amp; Sole Assembly, Boot</del>	<del>E</del>
	Right	
A7LB-106011	Sole Assembly, Right	D
<del>A6L-126007</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-126033</del>	<del>Pattern</del>	<del>C</del>
A7L-106012	Nut, Flanged	B
<del>A7L-126031</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-126032</del>	<del>Pattern</del>	<del>D</del>
	One - ST Drawing	B
<del>A7LB-106010</del>	<del>Heel Assembly, Boot</del>	<del>D</del>
<del>A7L-1S6029</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-1S6075</del>	<del>Pattern</del>	<del>C</del>
	One - ST Drawing	B
A7L-106010	Screw, Heel Shank	B
A7L-106013	Screw, Arch Shank	B
<del>A7L-106016</del>	<del>Insole Assembly, Restraint Right</del>	<del>D</del>
<del>A7L0126034</del>	<del>Pattern</del>	<del>D</del>
	Two - ST Drawings	B
A7L-106014	Arch/Heel, Shank	C
<del>A7L-1S6077</del>	<del>Pattern</del>	<del>B</del>
<del>A7L-1S6077</del>	<del>Pattern</del>	<del>B</del>
<del>A7L-1S6077</del>	<del>Pattern</del>	<del>B</del>
<del>A7L-1S6078</del>	<del>Pattern</del>	<del>B</del>
<del>A7L-1S6078</del>	<del>Pattern</del>	<del>B</del>
A7L-106005	Restraint Assembly, Boot Right	D
<del>A7L-126001</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-126002</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-1S6008</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-1S6021</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-1S6036</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-126048</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-126047</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-106007</del>	<del>Cable &amp; Ferrule Assembly, Boot</del>	<del>C</del>
A6L-106007	Ferrule, Cord Guide, Small	C
A7L-106007	Tube, Shrinkable	C
A7L-106007	Tube, Shrinkable	C
	Two - ST Drawings	B
A6L-106007	Ferrule, Cord Guide, Small	C
<del>A7L-126025</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-126024</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-126022</del>	<del>Pattern</del>	<del>D</del>
<del>A7L-1S6017</del>	<del>Pattern</del>	<del>C</del>
	Sixteen - ST Drawings	B
	Five - ST Drawings	B
	One - ST Drawing	B
A7LB-101270	Swage Fitting, Crotch Cable	C
A7LB-101271	Thimble, Crotch Cable	D
<del>A7LB-101272</del>	<del>Cable Coating Mod., Nylon</del>	<del>C</del>

A7LB-105004	Leg Assembly, TL5A Left	E
<del>A7LB-105045</del>	<del>Restraint Assembly, Lower Leg Cone,</del>	
	<del>Left</del>	D
<del>A7LB-1S5039</del>	<del>Pattern</del>	D
<del>A6L-105015</del>	<del>Flap &amp; Slide Fast. Assembly</del>	C
<del>A6L-1Z5003</del>	<del>Pattern</del>	D
	Two - ST Drawings	B
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
<del>A6L-1C9001</del>	<del>Tape, Loop, Modified</del>	C
	Eight - ST Drawings	B
A6L-105031	Pulley Assembly, Cable Crotch	D
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
<del>A7LB-105026</del>	<del>Cover Assembly, Thigh Convolute, Left</del>	E
<del>A6L-103001</del>	<del>Loop, Tape, Modified</del>	C
<del>A6L-1S5029</del>	<del>Pattern</del>	B
<del>A7LB-1S5026</del>	<del>Pattern</del>	E
<del>A7LB-1S5027</del>	<del>Pattern</del>	E
	Six - ST Drawings	C
<del>A7LB-105024</del>	<del>Convolute Assembly, Thigh</del>	C
<del>A7LB-1S1419</del>	<del>Pattern</del>	D
<del>A7LB-1S5021</del>	<del>Pattern</del>	D
A7LB-105023	Convolute, Thigh	D
	One - ST Drawing	B
<del>A7LB-105033</del>	<del>Convolute Assembly, Knee</del>	D
A7LB-105036	Terminal, Cable Swaging	C
A7LB-105006	Convolute, Knee	D
	One - ST Drawing	B
<del>A7LB-105007</del>	<del>Restraint Assembly, Thigh Cone, Left</del>	E
<del>A7LB-1Z5006</del>	<del>Pattern</del>	D
<del>A6L-1Z5006</del>	<del>Pattern</del>	B
<del>A6L-1Z5007</del>	<del>Pattern</del>	B
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
	Eight - ST Drawings	B
<del>A7LB-105009</del>	<del>Bladder Assembly, Thigh Cone, Left</del>	E
<del>A7LB-1Z5010</del>	<del>Pattern</del>	D
<del>A7LB-1Z5009</del>	<del>Pattern</del>	D
<del>A7LB-101208</del>	<del>Strip Assembly, Attachment Vent</del>	D
A6L-105019	Disc, Medical Injection	B
<del>A6L-1S5024</del>	<del>Pattern</del>	B
	Five - ST Drawings	B
<del>A7LB-105008</del>	<del>Bladder Assembly, Lower Leg Cone,</del>	
	<del>Left</del>	D
<del>A7LB-1S5007</del>	<del>Pattern</del>	D
<del>A7LB-1S5008</del>	<del>Pattern</del>	D
<del>A7LB-101208</del>	<del>Strip Assembly, Attachment, Vent</del>	D
	Five - ST Drawings	B
<del>A6L-1050325</del>	<del>Cover Assembly, Knee Convolute</del>	D
<del>A6L-105032</del>	<del>Tape, Loop, Modified</del>	D
<del>A6L-1S5012</del>	<del>Pattern</del>	D
<del>A6L-1S5013</del>	<del>Pattern</del>	D

<del>A6L-1S5014</del>	<del>Pattern</del>	D
	Two - ST Drawings	B
<del>A7LB-1S5011</del>	<del>Pattern</del>	C
<del>A7LB-1S5018</del>	<del>Pattern</del>	C
<del>A7LB-1S5018</del>	<del>Pattern</del>	C
A6L-101044	Washer, Grommet	B
	Eight - ST Drawings	B
	Two - AN Drawings	A
A7LB-105004	Leg Assembly, TL5A Right	E
<del>A7LB-1C5045</del>	<del>Restraint Assembly, Lwr. Leg Cone,</del>	
	<del>Right</del>	D
<del>A7LB-1S5089</del>	<del>Pattern</del>	D
<del>A6L-105015</del>	<del>Flap &amp; Slide Fast. Assembly</del>	C
<del>A6L-1S5003</del>	<del>Pattern</del>	D
	Two - ST Drawings	B
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
	Eight - ST Drawings	B
A6L-105031	Pulley Assembly, Cable Crotch	D
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
<del>A7LB-105026</del>	<del>Cover Assembly, Thigh Convolute, Right</del>	E
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
<del>A6L-1S5029</del>	<del>Pattern</del>	B
<del>A7LB-1S5026</del>	<del>Pattern</del>	E
<del>A7LB-1S5027</del>	<del>Pattern</del>	E
	Six - ST Drawings	B
<del>A7LB-105024</del>	<del>Convolute Assembly, Thigh</del>	C
<del>A7LB-1S1419</del>	<del>Pattern</del>	D
<del>A7LB-1S5021</del>	<del>Pattern</del>	D
A7LB-105023	Convolute, Thigh	D
	One - ST Drawing	B
<del>A7LB-105033</del>	<del>Convolute Assembly, Knee</del>	D
A7LB-105036	Terminal, Cable Swaging	C
A7LB-105006	Convolute, Knee	D
	One - ST Drawing	B
<del>A7LB-105007</del>	<del>Restraint Assembly, Thigh Cone</del>	E
<del>A7LB-1Z5006</del>	<del>Pattern</del>	D
<del>A6L-1Z5006</del>	<del>Pattern</del>	B
<del>A6L-1Z5007</del>	<del>Pattern</del>	E
<del>A6L-1S5009</del>	<del>Pattern</del>	B
<del>A7L-1S4004</del>	<del>Pattern</del>	B
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
	Five - ST Drawings	E
<del>A7LB-105009</del>	<del>Bladder Assembly, Thigh Cone, Right</del>	E
<del>A7LB-1Z5009</del>	<del>Pattern</del>	D
<del>A7LB-101208</del>	<del>Strip Assembly, Attachment</del>	D
<del>A7LB-1Z5010</del>	<del>Pattern</del>	D
	Three - ST Drawings	B

<del>A7LB-105008</del>	<del>Bladder Assembly, Lower Leg Gono,</del>	
	<del>Right</del>	D
<del>A7LB-1S5007</del>	<del>Pattern</del>	D
<del>A7LB-1S5003</del>	<del>Pattern</del>	D
<del>A7LB-101208</del>	<del>Strip Assembly Attachment, Vent</del>	D
	<del>Five - ST Drawings</del>	B
<del>A6L-105032</del>	<del>Cover Assembly, Knee Convolute</del>	D
<del>A6L-105032</del>	<del>Tape, Loop, Modified</del>	D
<del>A6L-1S5012</del>	<del>Pattern</del>	D
<del>A6L-1S5013</del>	<del>Pattern</del>	D
<del>A7LB-105029</del>	<del>Cover and Transfer Hose Assembly, UCTA</del>	D
A7L-105003	Male Disconnect, Urine Transfer,	
	Mod.	C
A7LB-105015	Cover, Preformed UTCA	C
A7LB-1Z5019	Transfer Hose Assembly, UCTA	D
A6L-401042	Clamp, Mod, Preformed, Band Type	C
	Two - ST Drawings	B
A7L-104005	Plug	D
A7L-104005	Mounting Ring	D
A7L-104005	"O" Ring	D
	Ten - ST Drawings	B
	One - MS Drawing	A
	Two - AN Drawings	A
A7LB-101269	Sleeve Swage Fitting	D
<del>A7LB-101272</del>	<del>Cable, Covering, Modified</del>	C
<del>A6L-109001</del>	<del>Tape, Loop, Modified</del>	C
A7LB-109012	Screw, Hex, Socket Head, Cap	D
A7LB-101126	Torso Assembly, TLSA	J
<del>A7LB-101143</del>	<del>Restraint Assembly, Torso</del>	J
<del>A7LB-1C1420</del>	<del>Pattern</del>	D
<del>A7LB-1C1420</del>	<del>Pattern</del>	D
<del>A7LB-1C1421</del>	<del>Pattern</del>	C
<del>A7LB-1C1421</del>	<del>Pattern</del>	C
<del>A7LB-1C1173</del>	<del>Pattern</del>	J
<del>A7LB-1C1174</del>	<del>Pattern</del>	J
<del>A7LB-1C1307</del>	<del>Pattern</del>	J
<del>A7LB-1C1307</del>	<del>Pattern</del>	J
<del>A7LB-1C1307</del>	<del>Pattern</del>	J
<del>A7LB-1C1307</del>	<del>Pattern</del>	J
<del>A7LB-1S1415</del>	<del>Pattern</del>	C
<del>A7LB-1C1306</del>	<del>Pattern</del>	J
<del>A7LB-1C1306</del>	<del>Pattern</del>	J
<del>A7LB-1C1176</del>	<del>Pattern</del>	E
<del>A7LB-1C1176</del>	<del>Pattern</del>	E
<del>A7LB-1C1400</del>	<del>Pattern</del>	C
<del>A7LB-1C1400</del>	<del>Pattern</del>	C
<del>A7LB-1C1183</del>	<del>Pattern</del>	D
<del>A7LB-1C1183</del>	<del>Pattern</del>	D
<del>A7LB-1C1308</del>	<del>Pattern</del>	E
<del>A7LB-1C1308</del>	<del>Pattern</del>	E



<del>A7LB-1C1309</del>	<del>Pattern</del>	E
<del>A7LB-1C1309</del>	<del>Pattern</del>	E
<del>A7LB-1C1179</del>	<del>Pattern</del>	E
A7LB-101252	Hook, Donning Aid	C
<del>A7LB-101250</del>	<del>Donning Aid Assembly, Slide Fastener</del>	C
A7LB-101251	Eye, Donning Aid, Slide Fastener	C
	Three - ST Drawings	B
<del>A7LB-101232</del>	<del>Webbing Assembly, Rear, Neck Restraint</del>	
	Right	D
<del>A7LB-1S1321</del>	<del>Pattern</del>	D
<del>A7LB-1S1320</del>	<del>Pattern</del>	C
<del>A7LB-1S1322</del>	<del>Pattern</del>	C
<del>A7LB-101231</del>	<del>Fitting, Restraint, Neck, Rear</del>	C
	One - ST Drawing	B
<del>A7LB-101232</del>	<del>Webbing Assembly, Rear, Neck Restraint</del>	
	Left	D
<del>A7LB-1S1321</del>	<del>Pattern</del>	D
<del>A7LB-1S1320</del>	<del>Pattern</del>	C
<del>A7LB-1S1322</del>	<del>Pattern</del>	C
<del>A7LB-101231</del>	<del>Fitting, Restraint, Neck, Rear</del>	C
	One - ST Drawing	B
A7LB-101195	Fastener, Slide, Vertical	E
A7LB-101195	Fastener, Slide, Horizontal	E
<del>A7LB-1C1198</del>	<del>Pattern</del>	J
<del>A7LB-1C1198</del>	<del>Pattern</del>	J
<del>A7LB-101210</del>	<del>Lanyard Assembly, Donning</del>	D
<del>A7LB-101211</del>	<del>Hook</del>	D
	Three - ST Drawings	B
<del>A7LB-1S1245</del>	<del>Pattern</del>	C
<del>A7LB-1S1199</del>	<del>Pattern</del>	C
<del>A7LB-1C1198</del>	<del>Pattern</del>	J
<del>A7LB-1S1195</del>	<del>Pattern</del>	C
<del>A7LB-1S1193</del>	<del>Pattern</del>	C
<del>A7LB-1C1198</del>	<del>Pattern</del>	J
<del>A7LB-1S1190</del>	<del>Pattern</del>	D
<del>A7LB-1C1310</del>	<del>Pattern</del>	D
A7L-101017	Double Bar "D" Ring	B
<del>A7LB-1C1182</del>	<del>Pattern</del>	C
<del>A7LB-1C1182</del>	<del>Pattern</del>	C
<del>A7LB-1C1181</del>	<del>Pattern</del>	D
<del>A7LB-1C1181</del>	<del>Pattern</del>	D
<del>A7LB-1S1178</del>	<del>Pattern</del>	D
<del>A7LB-1C1175</del>	<del>Pattern</del>	D
<del>A7LB-1C1175</del>	<del>Pattern</del>	D
	Twenty-six - ST Drawings	B
<del>A7LB-101140</del>	<del>Bladder Assembly, Torso</del>	J
A7LB-101215	Patch Assembly, Stress Relief, Zipper	C
A7LB-1S1172	Pattern	C
A7LB-1S1301	Pattern	C

<del>A7LB-1S1301</del>	<del>Pattern</del>
	Two - ST Drawings
<del>A7LB-1Z1396</del>	<del>Pattern</del>
<del>A7LB-1S1414</del>	<del>Pattern</del>
<del>A7LB-101267</del>	<del>Pad, Protective, P/S Slide Fastener</del>
<del>A7LB-1S1406</del>	<del>Pattern</del>
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<del>A7LB-1S1407</del>	<del>Pattern</del>
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<del>A7LB-1C1136</del>	<del>Pattern</del>
<del>A7LB-1C1127</del>	<del>Pattern</del>
<del>A7LB-1S1156</del>	<del>Pattern</del>
<del>A7LB-1C1134</del>	<del>Pattern</del>
<del>A7LB-1C1135</del>	<del>Pattern</del>
<del>A7LB-1C1130</del>	<del>Pattern</del>
<del>A7LB-1C1133</del>	<del>Pattern</del>
<del>A7LB-1C1125</del>	<del>Pattern</del>
<del>A7LB-1C1138</del>	<del>Pattern</del>
<del>A7LB-1C1128</del>	<del>Pattern</del>
<del>A7LB-101208</del>	<del>Strip Attachment Assembly 15</del>
<del>A7LB-1S1386</del>	<del>Pattern</del>
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<del>A7LB-101208</del>	<del>Strip Attachment Assembly 14</del>
<del>A7LB-1S1385</del>	<del>Pattern</del>
	Two - ST Drawings
<del>A7LB-101208</del>	<del>Strip Attachment Assembly 13</del>
<del>A7LB-1S1384</del>	<del>Pattern</del>
	Two - ST Drawings
<del>A7LB-1Z1317</del>	<del>Pattern</del>
<del>A7LB-1Z1315</del>	<del>Pattern</del>
<del>A7LB-1C1325</del>	<del>Pattern</del>
<del>A7LB-1Z1318</del>	<del>Pattern</del>
<del>A7LB-1Z1316</del>	<del>Pattern</del>
<del>A7LB-1S1204</del>	<del>Pattern</del>
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<del>A7LB-1S1170</del>	<del>Pattern</del>
<del>A7LB-1S1158</del>	<del>Pattern</del>
<del>A7LB-1S1157</del>	<del>Pattern</del>
<del>A7LB-1S1154</del>	<del>Pattern</del>
<del>A7LB-1S1154</del>	<del>Pattern</del>
<del>A7LB-1S1153</del>	<del>Pattern</del>
<del>A7LB-1C1131</del>	<del>Pattern</del>
<del>A7LB-1C1131</del>	<del>Pattern</del>
<del>A7LB-1C1126</del>	<del>Pattern</del>
<del>A7LB-1C1126</del>	<del>Pattern</del>

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<del>A7LB-101208</del>	<del>Strip Attachment Assy 12</del>	E
<del>A7LB-151302</del>	<del>Pattern</del>	C
	Two-St Dwgs	B
<del>A7LB-101208</del>	<del>Strip Attachment Assy 6</del>	E
<del>A7LB-151284</del>	<del>Pattern</del>	C
	Two ST Drawings	B
<del>A7LB-101208</del>	<del>Strip Attachment Assy 5</del>	E
<del>A7LB-151283</del>	<del>Pattern</del>	C
	Two ST Drawings	B
<del>A7LB-101208</del>	<del>Strip Attachment Assy 4</del>	E
<del>A7LB-151282</del>	<del>Pattern</del>	C
	Two - ST Drawings	B
<del>A7LB-101208</del>	<del>Strip Attachment Assy 3</del>	E
<del>A7LB-151281</del>	<del>Pattern</del>	C
	Two - ST Drawings	B
<del>A7LB-101208</del>	<del>Strip Attachment Assy 2</del>	E
<del>A7LB-151280</del>	<del>Pattern</del>	C
	Two - ST Drawings	B
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	Eleven - ST Drawings	B
<del>A7LB-151311</del>	<del>Pattern</del>	C
<del>A7LB-151253</del>	<del>Pattern</del>	C
<del>A7LB-101234</del>	<del>Tape Assy, Front Neck Restr.</del>	C
	Two - ST Drawing	B
<del>A7LB-101324</del>	<del>Pattern</del>	C
<del>A7LB-101139</del>	<del>Patch Assy, Front Shoulder Cable</del>	C
	Two - ST Drawings	B
<del>A7LB-101138</del>	<del>Patch Assy, Back 'D' Ring</del>	E
<del>A7LB-151124</del>	<del>Pattern</del>	D
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A7LB-101017	'D' Ring, Double Bar	B
	Four - ST Drawings	B
<del>A7LB-101134</del>	<del>Patch Assy, Tether, Right</del>	C
	Two - ST Drawing	B
<del>A7LB-151252</del>	<del>Pattern</del>	C
<del>A7LB-151254</del>	<del>Pattern</del>	C
<del>A7LB-151250</del>	<del>Pattern</del>	C
<del>A7LB-151248</del>	<del>Pattern</del>	C
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<del>A7LB-101137</del>	<del>Patch Assy, Plss</del>	C
	Two - ST Drawings	B
<del>A7LB-101136</del>	<del>Patch Assy, Back Shldr. Cable</del>	C
	Two - ST Drawings	B
<del>A7LB-101135</del>	<del>Path Assy, Thigh Cable Guide</del>	C

[illegible]

Eighteen - ST Drawings  
Arm Assy., Lower, ITMG., Right

[illegible]

[illegible]

## Pocket Assembly, Datolist

<del>A7LB-201134</del>	<del>_____</del>	<del>Snap Fastener Assy.</del>	C
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<del>A7LB-251818</del>	<del>_____</del>	<del>Pattern</del>	E
<del>A7LB-251633</del>	<del>_____</del>	<del>Pattern</del>	C
<del>A7LB-201182</del>	<del>_____</del>	<del>Stiffener Assy.</del>	C
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<del>A7LB-251635</del>	<del>_____</del>	<del>Pattern</del>	C
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		Four - ST Drawings	B
		Eleven - ST Drawings	B
		Five - MS Drawings	A
A7LB-201155		Pocket Assembly, Checklist	J
<del>A7LB-201183</del>	<del>_____</del>	<del>Pocket Intfg., Estnr. Tape Assy.</del>	D
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		Two - ST Drawings	B
<del>A7LB-251170</del>	<del>_____</del>	<del>Pattern</del>	E
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A7LB-201127		Ring, Rectangular	D
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<del>A7LB-251955</del>	<del>_____</del>	<del>Pattern</del>	C
<del>A7LB-251367</del>	<del>_____</del>	<del>Pattern</del>	C
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<del>A7LB-251827</del>	<del>_____</del>	<del>Pattern</del>	E
		Eight - ST Drawings B	B
A7LB-201175		Pocket Assembly, Scissors	D
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<del>A7LB-251367</del>	<del>_____</del>	<del>Pattern</del>	D
		Five - ST Drawings	B
		Two - MS Drawings	A
A7LB-201039		Flange, Outer, Elec. Conn	C
A7LB-109000		Screw, Mach, Flat Hd	D
<del>A7LB-101130</del>	<del>_____</del>	<del>Pless Attachment Assy., Lower</del>	D
A7LB-101168		Bracket & Ring Assy., Pless Att. Lower	C
A7LB-101065		Ring, Pless Attachment	C
A7LB-101169		Bracket, Pless Attachment	D
A7LB-101171		Connector, D-Ring	C
A7LB-101170		Spring	C
A7LB-101173		Cover, Bracket, Lower Pless	C

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	One - ST Drawing
A7LB-104138	Ring, Wrist
A7LB-103056	Glove Assy., Comfort, Left
<del>A7LB-103058</del>	<del>Pattern</del>
	One - ST Drawing
A7LB-103056	Glove Assy., Comfort, Right
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	One - ST Drawing
A7LB-101121	Wristlet
<del>A7LB-201188</del>	<del>Crew Commander Ident. Band</del>
<del>A7LB-201180</del>	<del>Cover Assy., Pressure Gage</del>
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A7LB-109050	Cap Assy., Prv.
A7LB-201177	Torso Assy., Tmg.
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A7LB-201187	Nasa Emblem
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	Four - MS Drawings
	Six - ST Drawings
	Two - MS Drawings
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	Two - MS Drawings
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## Six - ST Drawings

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<del>A7LB-221644</del>	<del>Pattern</del>
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<del>A7LB-2C1641</del>	<del>Pattern</del>
Six - ST Drawings	
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<del>A7LB-251883</del>	<del>Pattern</del>
<del>A7LB-201176</del>	<del>Insulation Patch, Leg Restr.</del>
<del>A7LB-251729</del>	<del>Pattern</del>
<del>A7LB-251828</del>	<del>Pattern</del>
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<del>A7LB-2G1726</del>	<del>Pattern</del>
Eight - ST Drawings	
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<del>A7LB-201069</del>	<del>Spacer, Lanyard, Conn, UCD</del>
<del>A7LB-201066</del>	<del>Ring, Mounting, UCD, ITMG</del>
<del>A7LB-201065</del>	<del>Clamp, Mounting, UCD, ITMG</del>
Six - Drawings	
One - MS Drawing	
Two - AN Drawings	
A7L-101067	Neck Dam Assy.
<del>A7L-101074</del>	<del>Ring Assy., Neck Dam</del>
A7L-101075	Ring, Neck Dam
A7L-101074	Tab, Neck Dam
<del>A7L-101073</del>	<del>Tab, Lanyard, Neck Dam</del>
A7L-101076	Rivet, Modified
One - ST	
<del>A7L-101081</del>	<del>Label Assy.</del>
Two - ST Drawings	
<del>A7LB-101115</del>	<del>Label, Crew Name</del>
<del>A7L-121036</del>	<del>Pattern</del>
Four - ST Drawings	
<del>A7L-201143</del>	<del>Loop Assy., Belt.</del>
<del>A7L-251345</del>	<del>Pattern</del>
<del>A7L-251638</del>	<del>Pattern</del>

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	Two - ST Drawings
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<del>A7LB-206052</del>	<del>Strap Assy., Donning</del>
<del>A7LB-256012</del>	<del>Pattern</del>
	Two - ST Drawings
<del>A7LB-256013</del>	<del>Pattern</del>
<del>A7LB-2Z1854</del>	<del>Pattern</del>
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<del>A7LB-2Z1756</del>	<del>Pattern</del>
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<del>A7LB-2Z1776</del>	<del>Pattern</del>
<del>A7LB-2Z1767</del>	<del>Pattern</del>
<del>A7LB-251412</del>	<del>Pattern</del>
<del>A7LB-251367</del>	<del>Pattern</del>
<del>A7LB-201040</del>	<del>Slide Fastener Pin Half Only</del>
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	Fourteen - ST Drawings
A7LB-206051	Boot Assy., ITMG, Right
<del>A7LB-206052</del>	<del>Strap Assy., Donning</del>
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	Two - ST Drawings
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<del>A7LB-2Z1854</del>	<del>Pattern</del>
<del>A7LB-2Z1854</del>	<del>Pattern</del>
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<del>A7LB-2Z1764</del>	<del>Pattern</del>
<del>A7LB-2Z1768</del>	<del>Pattern</del>
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<del>A7LB-2Z1755</del>	<del>Pattern</del>
<del>A7LB-2Z1756</del>	<del>Pattern</del>
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<del>A7LB-2Z1853</del>	<del>Pattern</del>	<del>D</del>
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<del>A7LB-2Z1853</del>	<del>Pattern</del>	<del>D</del>
<del>A7LB-2Z1765</del>	<del>Pattern</del>	<del>D</del>
<del>A7LB-2Z1763</del>	<del>Pattern</del>	<del>E</del>
<del>A7LB-2Z1852</del>	<del>Pattern</del>	<del>D</del>
<del>A7LB-2Z1850</del>	<del>Pattern</del>	<del>E</del>
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<del>A7L-2Z1767</del>	<del>Pattern</del>	<del>E</del>
<del>A7L-251412</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-251367</del>	<del>Pattern</del>	<del>C</del>
<del>A7L-201040</del>	<del>Slide Fastener Pin Half Only</del>	<del>C</del>
<del>A7LB-2Z1836</del>	<del>Pattern</del>	<del>D</del>
<del>A7LB-2Z1851</del>	<del>Pattern</del>	<del>E</del>
	Fourteen - ST Drawings	<del>B</del>
	Ten - ST Drawings	<del>B</del>
	Two - MS Drawings	<del>A</del>

APPENDIX B

PRESENTATION - MANAGEMENT SYSTEMS STUDY

MANAGEMENT SYSTEMS STUDY

BY

ILC DOVER

CONTRACT NAS 9-6100

DECEMBER 73 - APRIL 74

## BACKGROUND:

ALL MAJOR NASA PROGRAMS UNDER NPC 200-2, NPC 250-1, AND NPC 500-1  
COVERS WIDE RANGE OF UNIQUE HARDWARE (SPACE SUITS TO SPACE CRAFTS)  
REQUIREMENTS ARE GENERAL AND ALL ENCOMPASSING  
STAFF MAINTAINED TO SUPPORT UNNECESSARY REQUIREMENTS

PAST PROGRAM COSTS INDICATE NEED TO DEVELOP SET OF SPACESUIT ORIENTED  
REQUIREMENTS.

HISTORICALLY, NEW SS MANAGEMENT SYSTEMS DEVELOPED FOR EACH NEW MAJOR PROGRAM  
PROGRAM DYNAMICS PRECLUDED THOROUGH CONSIDERATION OF:  
COMPATABILITY TO END ITEM  
LONG TERM COST IMPACT  
EFFECTS ON OTHER PROGRAM SYSTEMS AND PROCEDURES

NEED EXISTS TO:

- MODIFY EXISTING PROGRAM REQUIREMENTS FOR SUIT COMPATABILITY.
- OPTIMIZE AND RETAIN "TIME-TESTED" APOLLO/SKYLAB MANAGEMENT  
SYSTEMS FOR FUTURE PROGRAM USE.

**OBJECTIVE:**

- 1) ANALYZE REQUIREMENTS AND MANAGEMENT SYSTEMS USED ON APOLLO/SKYLAB  
SPACESUIT PROGRAM
- 2) IDENTIFY THOSE WITH HIGHEST COST SAVING POTENTIAL
- 3) DEVELOP ALTERNATIVES
- 4) PERFORM TRADE-OFF OF ADVANTAGES/DISADVANTAGES  
MEASURE AGAINST APOLLO/SKYLAB
- 5) PROPOSE GUIDELINES FOR FUTURE PROGRAM

## APPROACH

STUDY TEAM FORMED FROM EX-APOLLO/SKYLAB MANAGEMENT PERSONNEL

MAJOR PROBLEM AREAS IDENTIFIED

PRIORITIES ESTABLISHED BASED ON:

POTENTIAL SAVINGS

MAXIMUM UTILIZATION OF TEAM MEMBER EXPERTISE

## AREAS STUDIED:

CMO, BUSINESS MANAGEMENT, PROGRAM CONTROL, ENGINEERING, QUALITY

## 13 STUDY TASKS SELECTED FOR ANALYSIS

STUDY GROUNDRULES DEFINED TO INSURE COMMON BASE

ALTERNATIVES DEVELOPED

TRADE-OFFS PERFORMED

GUIDELINES PROPOSED FOR FUTURE PROGRAM USE

COST SAVINGS DEVELOPED (PER GROUP) AND COMBINED INTO TOTAL PROGRAM ORGANIZATION

PURPOSE OF STUDY

PERFORM A POST-CONTRACT MANAGEMENT SYSTEM ANALYSIS

EVALUATE MANAGEMENT SYSTEMS EFFECTIVENESS

OPTIMIZE SYSTEMS TO REDUCE COSTS DURING FUTURE PROGRAMS

PERFORM CONTRACTOR "SELF-CRITIQUE"



## APPROACH

STUDY TEAM FORMED FROM EX-APOLLO/SKYLAB MANAGEMENT PERSONNEL

MAJOR PROBLEM AREAS IDENTIFIED

PRIORITIES ESTABLISHED BASED ON:

POTENTIAL SAVINGS

MAXIMUM UTILIZATION OF TEAM MEMBER EXPERTISE

## AREAS STUDIED:

CMO, BUSINESS MANAGEMENT, PROGRAM CONTROL, ENGINEERING, QUALITY

## 13 STUDY TASKS SELECTED FOR ANALYSIS

STUDY GROUND RULES DEFINED TO INSURE COMMON BASE

ALTERNATIVES DEVELOPED

TRADE-OFFS PERFORMED

GUIDELINES PROPOSED FOR FUTURE PROGRAM USE

COST SAVINGS DEVELOPED (PER GROUP) AND COMBINED INTO TOTAL PROGRAM ORGANIZATION

STUDY TASKS:

PROGRAM MANAGEMENT

CMO

GOVERNMENT/CONTRACTOR MANAGEMENT REPORTS

ASTRONAUT FIELD OPTION ITEM CONTROL

IMPROVED CONFIGURATION MANAGEMENT METHODS

BUSINESS MANAGEMENT

ANALYSIS OF COST DATA

BUSINESS MANAGEMENT SYSTEM

PROGRAM CONTROL

MANUFACTURING DOCUMENTATION AND CONTROL SYSTEMS

PROGRAM PHASING PHILOSOPHY

ENGINEERING

INTERFACE CONTROL DOCUMENTATION

CONTRACT END ITEM SPECIFICATIONS

FIELD OPERATIONAL DOCUMENTATION

ENGINEERING ORGANIZATION

QUALITY

TRACEABILITY

INSPECTION AND IN-PROCESS VERIFICATION

## GROUND RULES

1. ILC MANAGEMENT SYSTEMS IN EFFECT DURING THE A7LB PROGRAM USED AS STUDY BASELINE.
2. COST SAVINGS IDENTIFIED IN TERMS OF REDUCED MAN MONTHS (BY SKILLS) TO PERFORM SIMILAR EFFORTS ON FUTURE PROGRAMS.
3. RECOMMENDATIONS PRESENTED AS GUIDELINES FOR FUTURE PROGRAMS.
4. PROPOSED GUIDELINES BASED ON STATE-OF-THE-ART ADVANCEMENT IN SUIT DESIGNS USED ON FUTURE PROGRAMS.
5. DELIVERY RATE ASSUMED TO BE ONE (1) SPACE SUIT EVERY 20 WORKING DAYS.
6. ON FUTURE PROGRAMS, ONLY ONE (1) QUAL TO BE PERFORMED USING WORST CASE PROJECTED MISSION(S) THROUGH LIFE OF CEI.
7. REQUIREMENTS OF NHB 5300.4 WILL BE APPLICABLE TO FUTURE PROGRAM QUALITY SYSTEMS.
8. MINIMAL CHANGE ACTIVITY AND MINIMAL DEPOT FLIGHT SUPPORT FOR FUTURE PROGRAM.

## PROGRAM MANAGEMENT

### TASKS

- 1) MANUFACTURING DOCUMENTATION AND CONTROL SYSTEMS.
- 2) IMPROVED CONFIGURATION MANAGEMENT/CONTROL METHODS.
- 3) GOVERNMENT/CONTRACTOR MANAGEMENT REPORTS.
- 4) PROGRAM PHASING PHILOSOPHY.
- 5) ASTRONAUT FIELD OPTION ITEM CONTROL.

## ENGINEERING DRAWINGS & MANUFACTURING DOCUMENTATION

PROBLEM - OVER 90% OF THE DRAWINGS CONTAINED REDUNDANT INFORMATION.

- 1) MANUFACTURING AND INSPECTION INSTRUCTIONS (TO'S) WERE UTILIZED AS THE PRIME INSTRUCTIONS FOR OPERATIONAL PERSONNEL RATHER THAN THE DRAWINGS.
  - A. SUBASSEMBLY DRAWINGS GENERATED WERE COMPLEX AND UNWIELDY. OPERATIONAL PERSONNEL HAD DIFFICULTY USING THEM.
  - B. DRAWINGS WERE PRODUCED AND PART NUMBERS ASSIGNED FROM AN ENGINEERING VIEWPOINT. MANUFACTURING REQUIREMENTS WERE NOT GIVEN PRIORITY.
- 2) TO'S CONTAINED ALL THE INFORMATION ON THE DRAWINGS AS WELL AS SUPPLEMENTARY INSTRUCTIONS REQUIRED TO FABRICATE A SPACE SUIT ASSEMBLY.
- 3) BOTH TO'S AND DRAWINGS WERE MAINTAINED -- DUAL CONTROL PROCEDURES.

## DATA COLLECTION AND DISSEMINATION

### PROBLEM:

VARIOUS DOCUMENTATION WAS GENERATED TO MEET CONFIGURATION AND MATERIAL TRACEABILITY REQUIREMENTS.

- 1) THE INITIAL EMPHASIS WAS PLACED ON CONTROLLING CONFIGURATION AND TRACEABILITY FOR SPACE SUITS BEING FABRICATED.
- 2) AS THE PROGRAM BECAME OPERATIONAL, ADDITIONAL REQUIREMENTS WERE ENCOUNTERED.
- 3) NEW DOCUMENTS WERE CREATED BY INDIVIDUAL DEPARTMENTS WITHOUT CONSIDERING UTILIZING OR MODIFYING EXISTING REPORTS.

RECOMMENDED GUIDELINES:

- 1) DELEGATE AUTHORITY FOR DATA COLLECTION AND DISSEMINATION TO ONE SPECIFIC GROUP.
- 2) DETERMINE AS EARLY AS PRACTICAL WHAT INFORMATION WILL BE REQUIRED WHEN THE PROGRAM BECOMES OPERATIONAL.
- 3) FUNNEL ALL ADDITIONAL REQUIREMENTS THROUGH THE DELEGATED GROUP FOR OPTIMIZATION OF DATA DISSEMINATION.

## PROGRAM PHASING PHILOSOPHY

### PROBLEM:

ANY DELAY OR REDESIGN DURING DESIGN VERIFICATION OR QUALIFICATION TESTING HAS A DOMINO EFFECT ON THE SUBSEQUENT PROGRAM MILESTONES.

- 1) DVT WAS CONCURRENT WITH THE FABRICATION OF THE QUALIFICATION UNIT AND QUALIFICATION WAS PARALLEL TO THE FABRICATION OF PRODUCTION SPACE SUITS.
- 2) "FINE TUNING" CHANGES WERE INCORPORATED IN DVT AND QUALIFICATION UNITS WITHOUT COST TRADE-OFF STUDIES.
- 3) THE DVT AND QUALIFICATION PROCEDURES WERE BASED ON MISSION REQUIREMENTS OF AN ENTIRE SPACE SUIT ASSEMBLY.
  - A. PROGRAM SCHEDULES WERE BASED ON THE ENGINEERING DEFINITION OF THE LONGEST DURATION.



- 4) THE DESIGN ENGINEERS COULD NOT ADEQUATELY TRAIN THE PROJECT, MANUFACTURING AND QUALITY ENGINEERS PRIOR TO FABRICATION OF THE DESIGN VERIFICATION SPACE SUIT.
- 5) THE SUIT CONTRACTOR AND THE GOVERNMENT ARE INVOLVED IN WHAT CHANGE IS OR ISN'T FEE BEARING DURING QUALIFICATION TESTING.

RECOMMENDED GUIDELINES:

- 1) ESTABLISH REQUIRED CYCLE LIFE OF EACH MAJOR SUBASSEMBLY ARMS, LEGS, GLOVES, ETC. AND PERFORM CYCLE QUALIFICATION AND DESIGN VERIFICATION OF THESE SUBASSEMBLIES IN SERIES. (2. sec 652)
- 2) ALLOW ENOUGH DEVELOPMENT TIME TO PERMIT THE DESIGN ENGINEERS TO ALLOCATE TIME TO PROJECT, MANUFACTURING AND QUALITY ENGINEERING.
- 3) COST TRADE-OFF STUDIES SHOULD BE ACCOMPLISHED BEFORE INCORPORATION OF "FINE TUNING" CHANGES IN DVT OR QUALIFICATION UNITS ONCE FABRICATION HAS STARTED.
- 4) PERFORMING DVT AND QUALIFICATION TESTING ON A SUBASSEMBLY BASIS ALLOWS ADDITIONAL FLEXIBILITY WHILE PERFORMING TESTING, THUS REDUCING DELAYS CAUSED BY QUALIFICATION FAILURES OR UNANTICIPATED DELAYS IN RELEASING ACCEPTABLE ENGINEERING DEFINITION.
- 5) FIRST ARTICLE CONFIGURATION INSPECTION COULD BE PERFORMED UPON COMPLETION OF QUALIFICATION TESTING OF EACH SUBASSEMBLY.

# PROGRAM COMPARISON

PROPOSER A7LB  
 SUBASSEMBLY SPACE SUIT  
 QUALIFICATION & DVT QUALIFICATION & DVT

TASK

DEVELOPMENT (TO FAB DVT UNITS)	8 MONTHS	6 MONTHS
DVT	*6 MONTHS	6 MONTHS
QUALIFICATION	7 MONTHS	15 MONTHS
QUAL COMPLETE	20 MONTHS AFTER GO	30 MONTHS AFTER GO

\*UP TO 2 MONTHS ALLOWABLE SLIPPAGE WITHOUT PROGRAM IMPACT.

## IMPROVED CONFIGURATION MANAGEMENT CONTROLS & METHODS

### PROBLEM #1 - COMPLEX DRAWINGS & CONTROL SYSTEMS EXISTED DUE TO MULTIPLE CONFIGURATION CHANGES

- 1) 115 DIFFERENT CONFIGURATIONS WERE  
CREATED ON THE A7L PGA DRAWINGS
- 2) THE MULTITUDE OF DIFFERENT CONFIGURATIONS  
MADE THE DRAWINGS DIFFICULT TO INTERPRET
- 3) IDENTIFICATION OF CONFIGURATION DIFFERENCES  
REQUIRED TIME-CONSUMING PAPER SEARCHES  
WHEN CHANGES OCCURRED AT COMPONENT OR  
LOWER CONFIGURATION LEVELS
- 4) QUALIFICATION STATUS IDENTIFICATION WAS  
NOT READILY APPARENT
- 5) APPROXIMATELY 50 CMO-RELATED DOCUMENTS  
WERE ACTIVE DURING THE SKYLAB/ASTP  
PROGRAM
- 6) MANUFACTURING & QUALITY ORIGINATED  
ADDITIONAL DOCUMENTATION FOR TRACE  
AND ACCOUNTABILITY REQUIREMENTS

## RECOMMENDED GUIDELINES

1) IMPLEMENT AN AUTHORIZED CONFIGURATION AND TRACEABILITY SYSTEM WHICH WOULD CONSOLIDATE INTER-RELATED MANUFACTURING, QUALITY AND CMO DATA.

A) A PROPOSED SYSTEM, WHICH IS INCLUDED IN THE FINAL REPORT, SHOULD BE CONSIDERED FOR FUTURE SPACE SUIT PROGRAMS

2) UTILIZING 2 BASIC FORMS THE SYSTEM WOULD PROVIDE ALL NECESSARY CONTROL DATA WHICH INCLUDES:

AD VS. AB CONFIGURATION  
CLASSIFICATION

SIZE

QUALIFICATION STATUS

INTERCHANGEABILITY

BILLS OF MATERIALS

DRAWINGS

MOD KIT STATUS

TRACEABILITY

DELIVERY SCHEDULE

## IMPROVED CONFIGURATION MANAGEMENT CONTROLS/METHODS

PROBLEM #2: INCORPORATION OF ACCEPTABLE ALTERNATE  
PARTS REQUIRED FORMAL CONFIGURATION CHANGES.

- 1) PER THE CEI SPEC. EACH COMPONENT COULD ONLY  
BE REPLACED WITH OTHER COMPONENTS HAVING THE  
SAME PART NUMBER.
- 2) EXISTING SPARE PARTS WERE MODIFIED OR NEW  
PROCUREMENT WAS AUTHORIZED BECAUSE AN  
INTERCHANGEABILITY VEHICLE DID NOT EXIST.

RECOMMENDED GUIDELINES:

A SYSTEM SHOULD BE DEVELOPED TO IDENTIFY AND CONTROL  
USE OF ACCEPTABLE ALTERNATE PARTS.

## GOVERNMENT/CONTRACTOR MANAGEMENT REPORTS

### PROBLEM:

SIMILAR REPORTS WERE PREPARED BY DIFFERENT CONTRACTOR GROUPS.

- 1) MOST REPORTS WERE UNCONTROLLED, REQUIRING NO FORMAL REVIEW AND/OR CONCURRENCE PRIOR TO RELEASE.
- 2) NO CENTRAL DATA SOURCE EXISTED AND RESULTED IN CUSTOMER AND CONTRACTOR COUNTERPARTS FAVORING EACH OTHER'S DATA (CMO, ENGINEERING, QA & R, ETC.).
- 3) EACH INTERDEPARTMENTAL GROUP OF THE SUIT CONTRACTOR CREATED AND MAINTAINED THEIR OWN FILES TO PERFORM THEIR DAILY TASKS.
  - A. AT LEAST 11 REDUNDANT FILES EXISTED AT THE CONTRACTOR'S FACILITY. IN SOME CASES 50 DIFFERENT CMO-RELATED DOCUMENTS WERE INCLUDED IN FILES.
  - B. REORGANIZATION & RELOCATION OF INTER-DEPARTMENTAL GROUPS CAUSED MUCH DUPLICATION.....
- 4) RANDOM DISTRIBUTION TECHNIQUES. THE ORIGINATOR OF THE DATA IN MANY CASES ESTABLISHED HIS OWN DISTRIBUTION REQUIREMENTS.



RECOMMENDED GUIDELINES:

UTILIZE A DATA CENTRALIZATION SYSTEM TO:

- A. MONITOR AND CONTROL ALL DATA DISTRIBUTIONS.
- B. MONITOR THE DATA REPRODUCTION POLICIES.
- C. UTILIZE ONE CENTRAL DATA SOURCE TO INPUT ALL NEW DATA.

## ASTRONAUT FIELD OPTION ITEM CONTROL

### PROBLEM:

FIELD OPTIONAL MODIFICATIONS RESULTED IN CONFIGURATION CHANGES, MULTIPLE DRAWING REVISIONS, ADDITIONAL TRACKING SYSTEMS AND MASSIVE HISTORICAL FILES.

- 1) APPROXIMATELY 30 FIELD OPTIONAL ITEMS (FOI'S) WERE AVAILABLE IN ANY COMBINATION TO THE CREWMAN.
- 2) CREWMAN GENERALLY SELECTED FOI'S DURING THE SUIT FIT CHECK.
  - A. TIME WOULD NOT ALLOW INCORPORATION FOR VERIFICATION.
  - B. ON INITIAL FIELD USE OCCASIONALLY NEW FIT PROBLEMS OCCURRED.
- 3) STANDARD FOI'S WERE SHIPPED AS PART OF THE SUIT CONFIGURATION WHEN NOT DESIRED BY THE CREWMAN (VALSALVA DEVICE, COMFORT PADS, ETC.).

4) FOI'S IN MANY CASES WERE NEVER UTILIZED IN THE FIELD.

5) SEPARATE FIELD OPTIONAL ITEMCLISTS (FOIL'S) WERE PREPARED FOR EACH CEI AND SEPARABLE COMPONENT.

RECOMMENDED GUIDELINES:

- 1) INSTALL ALL FIELD OPTIONAL ITEMS IN THE FIELD.
- 2) IDENTIFY AND CONTROL FOI'S AT A TYPE II LEVEL.  
PREPARE THE LISTING OF FOI'S AS A TYPE II  
DOCUMENT.
  - A. DO NOT MAKE FOI'S PART OF THE CONTROLLED  
DRAWING SYSTEM.
- 3) PROVIDE FOI'S ONLY WHEN SPECIFICALLY REQUESTED  
BY THE CREWMAN.

## ENGINEERING

### OBJECTIVE: OPTIMIZE SELECTED ENGINEERING SYSTEMS AND ORGANIZATION

- EVALUATE A7LB BASELINE
- IDENTIFY HIGH COST AREAS
- SELECT STUDY AREAS
- IDENTIFY AND ANALYZE PROBLEMS
- PROVIDE GUIDELINES FOR FUTURE PROGRAM

### AREAS STUDIED: ICD SYSTEM

CEI SPECIFICATIONS

FIELD OPERATIONAL DOCUMENTS

ENGINEERING ORGANIZATION

## INTERFACE CONTROL DOCUMENTS (ICD)

### PROBLEM:

NUMEROUS ICD CHANGES OCCURRED WHICH HAD NO EFFECT ON INTERFACE  
EQUIPMENT EFFECTIVITY CHANGES

IDENTIFIED SUIT AND VEHICLE PER FLIGHT

31 ON ASTP PROGRAM ALONE

DASH NUMBER CHANGES

PROVIDED NO USEFUL INFORMATION

IRN REQUIRED EACH TIME CEI CONFIGURATION CHANGED

CEI WEIGHT CHANGES

SUIT WEIGHTS NOT FIXED LIKE HARDWARE

### GUIDELINES:

DELETE REQUIREMENT TO SHOW EFFECTIVITIES, DASH NUMBERS AND WEIGHTS ON ICD'S.

USE DOCUMENT SIMILAR TO SKYLAB STOWAGE LIST TO CONTROL WEIGHTS AND  
EQUIPMENT EFFECTIVITIES.

**PROBLEM:** ICD COORDINATION BETWEEN NASA CENTERS PERFORMED WITHOUT SUIT  
CONTRACTOR SUPPORT.

LEVEL A ICD'S USED FOR INTERCENTER INTERFACE DEFINITION  
EXAMPLE: PGA (JSC) TO OWS EVA FOOT RESTRAINT (MSFC)

CONTRACTOR DID NOT SIGN ICD'S

ICD CHANGES APPROVED WITHOUT CONTRACTOR COGNIZANCE

MISTAKES WERE MADE WHICH CAUSED COSTLY CORRECTIVE ACTION

**GUIDELINES:** DO NOT USE INTERCENTER ICD'S UNLESS REQUIRED.

IF USED, REQUIRE CONTRACTOR SIGNATURE ON ICD TO INSURE COORDINATION

**PROBLEM:** ICD SYSTEM REQUIRED THAT EACH INDIVIDUAL INTERFACE BE DOCUMENTED SEPARATELY. ADDITIONALLY, "ROLL" SIZE DRAWINGS USED WHERE UNNECESSARY.

RESULTED IN A TOTAL OF 186 ICD'S DURING PROGRAM

DUPLICATION OF DATA OCCURRED BETWEEN CONTRACTORS

SAME SUIT DIMENSIONS SHOWN BY CONTRACTORS (CONNECTORS)

DATA PRESENTED WHICH WAS NOT NECESSARY TO CONTROL INTERFACE

EXAMPLE: BUDDY SLSS TO PGA SHOWED SUITED CREWMAN WHILE  
REQUIRED DATA EXISTED ON ANOTHER ICD.

ROLL SIZE DRAWINGS WERE EXPENSIVE TO MAKE AND DIFFICULT TO  
HANDLE AND STORE.

CONTRACTORS WERE REIMBURSED ACCORDING TO ICD SIZE.

**GUIDELINES:**

DOCUMENT ALL SUIT ICD'S IN ONE DOCUMENT IN SPECIFICATION FORMAT  
CONTRACTORS WOULD REFERENCE SUIT ICD SPEC ON THEIR ICD'S  
PRECLUDES NEED FOR DUPLICATION



## CEI SPECIFICATIONS

### PROBLEM:

NUMEROUS CHANGES TO CEI SPECIFICATIONS

CEI WEIGHT CHANGES

SEPARABLE COMPONENTS REQUIRED CLOSE TRACKING  
EXCESSIVE CHANGE ACTIVITY OCCURRED DURING  
PROGRAM

CREW OPTION ITEMS

ADDED THROUGHOUT PROGRAM  
EFFECTED WEIGHT AND CREW OPTION ITEM LIST

ICD TABULATION

CHANGES OCCURRED AT HIGH RATE THROUGHOUT  
PROGRAM

### GUIDELINES:

ALLOW SUFFICIENT SAFETY FACTOR ON SPEC WEIGHT

DELETE REQUIREMENT TO REFLECT ICD LIST IN CEI SPECS  
CUSTOMER SIGNATURE ON ICD SHOULD SUFFICE

DELETE CREW OPTION LIST FROM CEI SPEC AND CONTROL  
BY OTHER LOWER LEVEL DOCUMENT.

**PROBLEM:**

REPETITION OF INFORMATION IN NUMEROUS CEI SPECIFICATIONS  
12 CEI SPECS USED DURING PROGRAM  
"BOILER PLATE" COMPRISED 60% OF DOCUMENTS  
(ENVIRONMENTS, DESIGN REQUIREMENTS, MSCM 8080 REQUIREMENTS, ETC).  
REQUIREMENT CHANGE TO "BOILER PLATE" CAUSED 12 DOCUMENTS TO CHANGE  
EACH CHANGE HAD TO BE SUBMITTED ON SEPARATE ECP

**GUIDELINES:**

ONE CEI SPECIFICATION BE USED TO DEFINE TOTAL SPACESUIT SYSTEM REQUIREMENTS.

OPTIMIZATION OF FIELD OPERATING PROCEDURES

MAINTENANCE MANUAL

ILLUSTRATED PARTS BREAKDOWN

PROBLEM:

EXPENSIVE TO PREPARE AND MAINTAIN  
CONTAINED HIGH LEVEL OF TECHNICAL DETAIL  
ILLUSTRATIONS EXPENSIVE

ALL CLASS I AND II CONFIGURATIONS MAINTAINED  
3 MODELS AT ONCE  
OTHER OPERATIONAL DIRECTIONS (FOB'S, SSN, SRP)

REFERENCES RESTRICTED

SEPARATE AND DIFFERENT INSTRUCTIONS AT DEPOT AND  
FIELD

TO'S FOR NEW FAB.  
MM FOR TEARDOWN AND REBUILD  
MM RESTRICTED TO NON-STRUCTURAL REPAIRS

CHANGE ACTIVITY EXCESSIVE  
1970 - 1971, - 80 CHANGES EFFECTING 2378  
PAGES, 173 ILLUST.

LEVEL-OF-EFFORT METHOD OF MAINTENANCE  
CHANGES DIRECTED W/O REGARD TO COST  
INITIAL STANDARD MAINTAINED

**GUIDELINES:**

- AUTHORIZE ALL MAINTENANCE IN FIELD.
- UTILIZE TO'S WHERE PRACTICAL  
PROVIDE TEARDOWN SECTION TO SUPPLEMENT TO'S
- PERMIT MORE USE OF REFERENCES.  
MAKE MORE USE OF GENERAL SECTION FOR NOTES, CAUTIONS, ETC.  
ALLOW USE OF ONE ILLUSTRATION TO SHOW SIMPLE CONFIGURATION  
DIFFERENCES.  
UTILIZE OTHER DOCUMENTATION IN LIEU OF REPEATING IN MM.
- HANDLE CHANGES ON A CCA BASIS.

**OPTIMIZE ENGINEERING ORGANIZATION FOR FUTURE SPACESUIT PROGRAM.**

**AREAS STUDIED:**

**QUALIFICATION SUPPORT**

**ASTRONAUT FIT CHECKS**

**ENGINEERING RESPONSIBILITIES**

**USE OF DESIGN VERSUS MANUFACTURING ENGINEERING**

**LIMITED COMPANY ENGINEERING POOL**

**PROBLEM:**

CHANGING MISSION REQUIREMENTS CAUSED CONTINUOUS QUAL EFFORT  
ACTIVE TESTING 29 OF 49 MONTH PERIOD  
PREPARATION AND REPORT TIME MADE ACTIVITY CONTINUOUS  
ENGINEERING SUPPORT TIME ESTIMATED AT 196 MM  
MISSION C & J (2 MODELS, 2 QUALS) REQUIRED 90 MM

**GUIDELINES:**

IDENTIFY TOTAL CYCLE LIFE REQUIREMENTS PRIOR TO TESTING OR ENDURANCE  
TEST IF NOT AVAILABLE  
TRADE-OFF QUAL FAILURES REDESIGNS VERSUS LIMITING LIFE OF ITEM  
QUAL BY SUBASSEMBLIES IN LIEU OF TOTAL CEI

MINIMIZE OVERTESTING  
REALISTIC SAFETY FACTORS  
REALISTIC MOBILITY REQUIREMENTS  
"YOUNG'S ROCKS", "0" G EFFECTS

**PROBLEM:**

ASTRONAUT FITCHECK PERFORMED AT DEPOT

PGA DESIGN REQUIRED DEPOT FITCHECK

*Question this* — 52 MH ENGINEERING SUPPORT/FITCHECK

OTHER REQUIRED SUPPORT

TECHNICIANS, QUALITY PERSONNEL, PROGRAM PERSONNEL

INEFFICIENT ALLOCATION OF ASTRONAUT TRAINING TIME

SCHEDULE PROBLEMS

EXPENSIVE GFE REQUIREMENTS

ASTRONAUT TRAVEL COSTS

**GUIDELINES:**

PERFORM FITCHECK AT USER FACILITY

FINAL ACCEPTANCE SUBJECT TO ACCEPTABLE FIT CHECK

DESIGN SHOULD PRECLUDE USE OF SIZING CABLES



**PROBLEM:**

DUPLICATION OF RESPONSIBILITIES  
LIAISON ENGINEERS PERFORMED CHECK AND BALANCE LIKE CMO  
ACTIVITY JUSTIFIED DURING EXTENSIVE CHANGE

REDUCED DRAWING REQUIREMENTS REDUCES NEED FOR GROUP

**GUIDELINES:**

DELEGATE RESPONSIBILITY TO CMO TO PERFORM CHANGE ACTIVITY FUNCTIONS  
ELIMINATES REDUNDANCY  
ENGINEERING GROUP RETAINS TECH RESPONSIBILITIES

PROBLEM:

LIMITED COMPANY RESOURCES REQUIRED RETENTION OF ENGINEERING SKILLS

EXTENSIVE ENGINEERING EXPERTISE REQUIRED

NO LARGE COMPANY POOL FOR DRAWING SPECIALIST TALENT

REQUIREMENT TO SOLVE ALL SUIT PROBLEMS

                    DICTATED SKILL RETENTION

OPTIONS:

NASA SUPPLY SERVICES WHEN SPECIALIST SKILL REQUIRED

NASA PERFORM FAILURE ANALYSIS WITH CONTRACTOR ASSISTANCE

NASA RETAIN RESPONSIBILITY OF MODIFICATION DESIGN

CONTRACTOR PERFORM RETROFITS AND MOD KIT FAB.

PROBLEM:

ILC MANUFACTURING ENGINEERS GIVEN LIMITED RESPONSIBILITY

REQUIRED ACTIVE DESIGN ENGINEERING SUPPORT

MANUFACTURING ENGINEERS NOT INVOLVED DURING DESIGN PHASE

DESIGN ENGINEERS WROTE INSTRUCTIONS AND SOLVED PROBLEMS

MANUFACTURING ENGINEER PRIMARILY SUPERVISOR

CELL CONCEPT EFFECTIVE BUT COSTLY

GUIDELINES:

MANUFACTURING ENGINEER INVOLVEMENT DURING DEVELOPMENT PHASE

DISCREPANCY AND CRITICALITY LEVEL DEFINED EARLY IN PROGRAM

DESIGN ENGINEER SERVE AS SUPPORT ON AS-NEEDED BASIS

MANUFACTURING ENGINEER GIVEN INCREASED RESPONSIBILITY ON DR'S

## PRODUCT ASSURANCE

### OBJECTIVE: DEFINE MORE EFFICIENT ORGANIZATION

- REVIEW A7LB ORGANIZATION
- IDENTIFY AREAS FOR IMPROVEMENT
- IDENTIFY PROBLEMS
- DEFINE NEW PROGRAM GUIDELINES

### AREAS STUDIED:

- TRACEABILITY
- IN-PROCESS VERIFICATION/INSPECTION

## INSPECTION & IN-PROCESS VERIFICATION

### PROBLEM:

AMOUNT OF IN-PROCESS DISCREPANCY PAPER, PRODUCTION  
"DOWN TIME" AND MANPOWER REQUIRED TO CLEAR PAPER WORK.

- 1) THE TOLERANCES ON VARIOUS DIMENSIONS WERE  
"TIGHT" TO INSURE QUALITY WORKMANSHIP.
- 2) 100% INSPECTION WAS PERFORMED ON ALL ITEMS IN  
PRODUCTION.
- 3) MANUFACTURING ENGINEERING WAS NOT DELEGATED ANY  
RESPONSIBILITY FOR DISPOSITIONING A REJECT.
  - A. EACH REJECT TAG REQUIRED AN AVERAGE OF ONE HOUR  
TO PROCESS.
  - B. MAJOR AND MINOR DEFECTS WERE NOT CLASSIFIED AND  
INDICATED ON THE INSPECTION INSTRUCTIONS

## PROGRAM GUIDELINES:

- 1) INSURE ALL TOLERANCES ARE PRACTICAL PRIOR TO RELEASE OF DVT PRODUCTION DOCUMENTATION. THE RESULTS SHOULD BE REVIEWED AFTER DVT, AND TOLERANCES REVISED AS NECESSARY FOR THE QUALIFICATION UNITS.
- 2) CLASSIFICATION OF DEFECTS
- 3) A MINIMUM OF IN-PROCESS INSPECTION SHOULD BE PERFORMED BY QUALITY. THE EMPHASIS SHOULD BE PLACED ON SUBASSEMBLY INSPECTION AND TESTING.
- 4) MANUFACTURING SHOULD BE DELEGATED GREATER RESPONSIBILITY FOR IN-PROCESS INSPECTION.
- 5) MANUFACTURING ENGINEERING SHOULD BE RESPONSIBLE FOR DISPOSITIONING MINOR REJECTS. THIS WOULD ELIMINATE APPROXIMATELY 70% OF THE REJECT TAGS.

## TRACEABILITY

### PROBLEM:

HIGH LEVEL OF MANPOWER REQUIRED TO MAINTAIN  
TRACEABILITY SYSTEM.

STANDARD TRACE SYSTEM DEVELOPED INTO TOTAL  
HISTORICAL/VERIFICATION CAPABILITY.

CONTAINED ALL FIELD AND DEPOT TRACE DATA.  
MANUAL SYSTEM CAUSED HEAVY MANLOADING.

CRITICAL PARTS AND MATERIALS NOT IDENTIFIED.  
ALL MATERIALS TREATED EQUALLY  
REVIEW INDICATES 25% NEED NOT BE TRACED

VARIATION IN TYPES OF TRACE SYSTEMS UTILIZED  
(SHOP ORDERS, PIRS, FIRS)  
COMPLICATED DATA RECORDING AND RETRIEVAL  
INCREASED CHANCE OF ERRORS

VARIED AND REDUNDANT REQUESTS FOR DATA  
RETRIEVAL TIME CONSUMING  
TRACEABILITY MATRIX NOT FEASIBLE  
CAUSED HIGH LEVEL OF OVERTIME  
SOME REQUESTS OF NON-CRITICAL NATURE  
NO REQUEST SYSTEM OR REQUEST "CHAIN-OF-  
COMMAND" EXISTED

GUIDELINES:

METHOD I: STREAMLINE AND MAINTAIN A MANUAL SYSTEM  
RECORD ALL TRACE DATA BY ONE SYSTEM  
IDENTIFY NON-CRITICAL MATERIAL AND DO NOT  
TRACE BEYOND RECEIVING INSPECTION.  
DO NOT TRACE CLASS II CHANGES  
TRANSFER FILING AND MAINTENANCE TO A CENTRAL  
PROGRAM DATA CENTER.  
QUALITY TO MONITOR AND VERIFY ONLY.  
REDUCES QUALITY CLERK REQUIREMENTS.  
ESTABLISH "DATA REQUEST" CONTROLS AND PROCEDURES.

METHOD II: COMPUTERIZE DATA SYSTEM  
REDUCTION IN MANPOWER  
LESS FILING REQUIREMENTS  
FASTER AND MORE CONTROLLED RETRIEVAL  
MORE RELIABLE DATA  
CLASS II CAN BE TRACKED AT LITTLE INCREASE  
IN COST.



## SUMMARY

### MAJOR GUIDELINES RESULTING FROM STUDY:

- 1) PLACE EMPHASIS ON QUALIFICATION OF SUBASSEMBLIES RATHER THAN THE ENTIRE SPACESUIT ASSEMBLY.
- 2) FACI FIRST PRODUCTION ITEM RATHER THAN QUALIFICATION ITEM.
- 3) QUALIFY TO CEI WORST CASE MISSION REQUIREMENTS FIRST TIME
- 4) REDUCE DRAWING REQUIREMENTS BY USING MANUFACTURING INSTRUCTIONS FOR CONFIGURATION CONTROL.
- 5) REDUCE 100% IN-PROCESS INSPECTION -- REPLACE WITH COMPONENT AND SUBASSEMBLY ACCEPTANCE TESTING.
- 6) ALLOCATE SUFFICIENT TIME EARLY IN PROGRAM TO DEVELOP EFFICIENT SYSTEMS AND PROCEDURES.
- 7) PERFORM ASTRONAUT FIT CHECK AT USER'S SITE.
- 8) STREAMLINE DATA REPORTING REQUIREMENTS AND CENTRALIZE DATA COLLECTION SYSTEM.
- 9) CONSOLIDATE PROGRAM MANAGEMENT CONTROL FUNCTIONS.

POTENTIAL MANMONTH SAVINGS  
SUMMARY

TOTAL POTENTIAL SAVINGS  
1565 MANMONTHS